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DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Parts 523, 531, 533, 536, and 537

ENVIRONMENTAL PROTECTION AGENCY

40 CFR Parts 85 and 86

[NHTSA-2018-0067; EPA-HQ-OAR-2018-0283; FRL-9981-74-OAR-]

RIN 2127-AL76; RIN 2060-AU09

The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks

AGENCIES: Environmental Protection Agency and National Highway Traffic Safety Administration.

ACTION: Final Rule.

SUMMARY: EPA and NHTSA, on behalf of the Department of Transportation, are issuing final rules to amend and establish carbon dioxide and fuel economy standards. Specifically, EPA is amending carbon dioxide standards for model years 2021 and later, and NHTSA is amending fuel economy standards for model year 2021 and setting new fuel economy standards for model years 2022-2026. The standards set by this action apply to passenger cars and light trucks, and will continue our nation's progress toward energy independence and carbon dioxide reduction, while recognizing the realities of the marketplace and consumers' interest in purchasing vehicles that meet all of their diverse needs. These final rules represent the second part of the Administration's action related to the August 24, 2018 proposed Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule. These final rules follow the agencies' actions, taken September 19, 2019, to ensure One National Program for automobile fuel economy and carbon dioxide emissions standards, by finalizing regulatory text related to preemption under the Energy Policy and Conservation Act and withdrawing a waiver previously provided to California under the Clean Air Act.

DATES: This final rule is effective on [INSERT DATE 60 DAYS AFTER DATE OF PUBLICATION IN THE *FEDERAL REGISTER*].

ADDRESSES: EPA and NHTSA have established dockets for this action under Docket ID Nos. EPA-HQ-OAR-2018-0283 and NHTSA-2018-0067, respectively. All documents in the docket are listed in the http://www.regulations.gov index. Although listed in the index, some information is not publicly available, *e.g.*, confidential business information (CBI) or other information whose disclosure is restricted by statute. Certain other material, such as copyrighted material, will be publicly available in hard copy in EPA's docket, and electronically in NHTSA's online docket. Publicly available docket materials can be found either electronically in www.regulations.gov by searching for the dockets using the Docket ID numbers above, or in hard copy at the following locations:

EPA: EPA Docket Center, EPA/DC, EPA West, Room 3334, 1301 Constitution Ave., NW, Washington, DC. The Public Reading Room is open from 8:30 am to 4:30 pm, Monday through Friday, excluding legal holidays. The telephone number for the Public Reading Room is (202) 566-1744.

NHTSA: Docket Management Facility, M-30, U.S. Department of Transportation (DOT), West Building, Ground Floor, Rm. W12-140, 1200 New Jersey Ave., SE, Washington, DC 20590. The DOT Docket Management Facility is open between 9 am and 5 pm Eastern Time, Monday through Friday, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: *EPA*: Christopher Lieske, Office of Transportation and Air Quality, Assessment and Standards Division, Environmental Protection Agency, 2000 Traverwood Drive, Ann Arbor, MI 48105; telephone number: (734) 214-4585~~4~~; fax number: (734) 214-4816; email address: lieske.christopher@epa.gov, or contact the Assessment and Standards Division, email address: otaq~~publicweb~~@epa.gov. *NHTSA*: James Tamm, Office of Rulemaking, Fuel Economy Division, National Highway Traffic Safety Administration, 1200 New Jersey Avenue, SE, Washington, D.C. 20590; telephone number: (202) 493-0515.

Commented [A1]: **CHANGE AS SHOWN:** Please correct the EPA phone number and web address.

SUPPLEMENTARY INFORMATION:

Does this action apply to me?

This action affects companies that manufacture or sell new light-duty vehicles, light-duty trucks, and medium-duty passenger vehicles, as defined under EPA's CAA regulations,[1] and passenger automobiles (passenger cars) and non-passenger automobiles (light trucks) as defined under NHTSA's CAFE regulations.[2] Regulated categories and entities include:

Category	NAICS Codes[A]	Examples of potentially regulated entities
Industry.....	335111	Motor Vehicle Manufacturers.
	336112	
Industry.....	811111	Commercial Importers of Vehicles and Vehicle Components.
	811112	
	811198	
	423110	
Industry.....	335312	Alternative Fuel Vehicle Converters.
	336312	
	336399	
	811198	

[A] North American Industry Classification System (NAICS).

This list is not intended to be exhaustive, but rather provides a guide regarding entities likely to be regulated by this action. To determine whether particular activities may be regulated by this action, you should carefully examine the regulations. You may direct questions regarding the applicability of this action to the person listed in **FOR FURTHER INFORMATION CONTACT.**

[1] "Light-duty vehicle," "light-duty truck," and "medium-duty passenger vehicle" are defined in 40 CFR 86.1803-01. Generally speaking, a "light-duty vehicle" is a passenger car, a "light-duty truck" is a pick-up truck, sport-utility vehicle, or minivan up to 8,500 lbs gross vehicle weight rating, and a "medium-duty passenger vehicle" is a sport-utility vehicle or passenger van from 8,500 to 10,000 lbs gross vehicle weight rating.
[2] "Passenger car" and "light truck" are defined in 49 CFR Part 523.

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I. Executive Summary

NHTSA (on behalf of the Department of Transportation) and EPA are issuing final rules to adopt and modify standards regulating fuel economy and tailpipe carbon dioxide (CO_2) emissions ~~and use/leakage of other air conditioning refrigerants~~ for passenger cars and light trucks for MYs 2021-2026. These final rules follow the proposal issued in August, 2018 and respond to each agency's legal obligation to set standards based on the factors Congress directed them to consider, as well as the direction of the United States Supreme Court in *Massachusetts v. EPA*, which stated that "there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency."[3]

These standards apply to light-duty vehicles, which NHTSA divides for purposes of regulation into passenger cars and light trucks, and EPA divides into passenger cars, light-duty trucks, and medium-duty passenger vehicles (i.e., sport utility vehicles, cross-over utility vehicles, and light trucks). These standards are the product of significant and ongoing work by both agencies to craft regulatory requirements for the same group of vehicles and vehicle manufacturers. This work aims to facilitate, to the extent possible within the statutory directives issued to each agency, the ability of automobile manufacturers to meet all requirements under both programs with a single national fleet under one national program of fuel economy and tailpipe ~~CO_2~~ GHG emission regulations.

The agencies estimate that this final rule will save approximately [xxx] billion barrels of oil ~~as compared to holding the MY 2020 standards constant through MY 2026 (as proposed in the NPRM)~~ and reduce CO_2 emissions by approximately [xxx] million metric tons over the lifetimes of ~~those~~ passenger cars and light trucks produced in MYs 2021-2026 as compared to holding the MY 2020 standards constant through MY 2026 (as proposed in the NPRM). The agencies project that under the~~se~~ final standards, required technology costs ~~would~~ will be reduced by $[xxx], and, equally important, up-front vehicle costs to U.S. consumers for new vehicles ~~would~~ will be $[xxx] lower, on average, than they would have been if the agencies had retained the standards set forth in the 2012 final rule ~~and originally upheld by EPA in January 2017~~. While the~~se~~ final standards are estimated to result in [xxx] additional billion barrels of oil consumed and [xxx] additional million metric tons of CO_2 as compared to the current estimates of what ~~the~~ retaining the standards set forth in the 2012 final rule would have required, the agencies explain at length below why we believe the overall benefits of the final standards outweigh these additional costs. Overall (fleetwide) net benefits would have been higher if the agencies had decided that the proposed standards should be finalized, but both agencies have concluded that standards that increase in stringency by 1.5 percent per year better reflect the considerations ~~embodied in~~under their respective statutory ~~factors~~authorities, as also explained below.

Commented [A2]: **CHANGE AS SHOWN:** EPA is not modifying the regulations pertaining to air conditioning refrigenants/leakage.

Commented [A3]: **CHANGE AS SHOWN:** The EPA program includes GHGs other than CO2, including HFCs, methane, and nitrous oxides.

Commented [A4]: **CHANGE AS SHOWN:** Edits in this paragraph are for clarity and readability.

Commented [A5]: **REVISE:** Add cite if this is first reference to 2012 rule

Commented [A6]: **REVISE:** These statements are not consistent with the SAFE FRM technical analysis. As shown in Tables I-1, I-2, I-3, and I-4, for CO2 the final SAFE action has costs that outweight the benefits, while for CAFE the data shows under the 3% DR the costs outweigh the benefits, while under a 7% DR the benefits do outweigh the costs.

[3] 549 U.S. 497, 532 (2007).

EPA and NHTSA are finalizing separate sets of standards for passenger cars and for light trucks under their respective statutory authorities. EPA is ~~setting~~ revising its national tailpipe CO_2 emissions standards for passenger cars and light trucks under section 202(a) of the Clean Air Act (CAA).[4] ~~and under its authority to establish metrics and measure passenger car and light truck fleet fuel economy pursuant to the Energy Policy and Conservation Act (EPCA).[5]~~ NHTSA is setting national corporate average fuel economy (CAFE) standards under EPCA, as amended by the Energy Independence and Security Act (EISA) of 2007.[6]

Commented [A7]: CHANGE AS SHOWN: the EPCA citations are not relevant to the revised EPA CO2 standards.

Section 202(a) of the CAA requires EPA to establish standards for emissions of pollutants from new motor vehicles that cause or contribute to air pollution that may reasonably be anticipated to endanger public health or welfare. Standards under section 202(a) are to~~thus~~ take effect only "after providing "such period as the Administrator finds necessary to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period."[7] In establishing such standards, EPA ~~must~~ considers issues of technical feasibility, cost, and available lead time, among other things.

Commented [A8]: CHANGE AS SHOWN: Correcting references to CAA authority.

EPCA, as amended by EISA, contains a number of provisions governing how NHTSA must set CAFE standards. EPCA requires that the Department of Transportation establish separate passenger car and light truck standards[8] at "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year,"[9] based on the agency's consideration of four statutory factors: technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the United States to conserve energy.[10] EPCA does not define these terms or specify what weight to give each concern in balancing them—such considerations are left within the discretion of the Secretary of Transportation (delegated to NHTSA) based upon current information. Accordingly, NHTSA interprets these factors and determines the appropriate weighting that leads to the maximum feasible standards given the circumstances present at the time of promulgating each CAFE standard rulemaking. While EISA, for MYs 2011-2020, additionally required that standards increase "ratably" and be set at levels to ensure that the CAFE of the industry-wide combined fleet of new passenger cars and light trucks reach at least 35 mpg by MY 2020,[11] EISA requires that standards for MYs 2021-2030 simply be set at the maximum feasible level as determined by the Secretary (and by delegation, NHTSA).[12]

Sections III and VIII below contain detailed discussions of both agencies' statutory obligations and authorities.

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[4] 42 U.S.C. 7521(a).
~~[5] 49 U.S.C. 32904(c).~~
[6] 49 U.S.C. 32902.
[7] CAA Sec. 202(a); 42 U.S.C. 7521(a)(2).
[8] 49 U.S.C. 32902(b)(1).
[9] 49 U.S.C. 32902(a).
[10] 49 U.S.C. 32902(f).
[11] 49 U.S.C. 32902(b)(2)(A) and (C).
[12] 49 U.S.C. 32902(b)(2)(B).

As stated above, NHTSA and EPA are finalizing rules for passenger cars and light trucks that the agencies believe represent appropriate levels of CO_2 emissions standards and maximum feasible CAFE standards for MYs 2021-2026, pursuant to their respective statutory authorities. EPA is ~~establishing~~ finalizing standards that are projected to ~~require~~achieve, on an average industry fleet-wide basis, [xxx] grams/mile (g/mi) of CO_2 in model year 2026. NHTSA is establishing standards that are projected to require, on an average industry fleet-wide basis, [xx.x] miles per gallon (mpg) in model year 2026. The agencies note that real-world CO_2 is typically 25 percent higher and real-world fuel economy is typically 20 percent lower than the CO_2 and CAFE compliance values discussed here, and also note that a portion of EPA's expected "CO_2" improvements will ~~in fact~~ be made through improvements in minimizing air conditioning leakage and ~~through~~ use of alternative refrigerants, which will not contribute to fuel economy but will contribute toward reductions of ~~climate-related emissions~~GHGs.

Commented [A9]: **CHANGE AS SHOWN:** "standards that are projected to require X g/mi of CO2" is awkwardly worded.

Commented [A10]: **CHANGE AS SHOWN:** Corrections to GHG program references.

~~Both the~~ The final CAFE and CO_2 standards are vehicle-footprint-based, as are the standards currently in effect. The~~se~~ standards will become more stringent for each model year from 2021 to 2026, relative to the MY 2020 standards. Generally, the larger the vehicle footprint, the less numerically stringent the corresponding vehicle CO_2 and mpg targets. As a result of the footprint-based standards, the burden of compliance is distributed across all vehicle footprints and across all manufacturers. Each manufacturer is subject to individualized standards for passenger cars and light trucks, in each model year, based on the vehicles it produces. ~~When~~ The standards are carefully crafted, both in terms of the footprint curves and the rate of increase in stringency of those curves, so that manufacturers are not compelled to build vehicles of any particular size or type.

Commented [A11]: **REVISE:** This statement about increasing stringency from MY2020 needs to be reconciled with comments EPA has provided to NHTSA in late 2019 regarding the incorrect EPA CO2 standard coefficients in Section V (Regulatory Alternatives) of the draft preamble. As noted in this draft of the preamble in Section V, a number of the EPA standard coeffients are incorrect, and if not fixed, then the EPA CO2 stringency will not begin to increase from 2020 levels until 2022.

In the NPRM, the agencies sought comment on a variety of possible changes to existing compliance flexibilities that have been created over the past several years. The vast majority of the existing compliance flexibilities are not being changed, but a small number of flexibilities, including some related to real-world fuel efficiency improvements are being finalized. ~~In addition~~ As part of the unchanged flexibilities, EPA is making no changes ~~will continue~~ to the provisions allowing manufacturers to make improvements relating to air conditioning refrigerants and leakage and ~~will~~ generate credits for those improvements toward CO_2 compliance~~, and EPA is making no changes in the amounts of credits available~~. EPA is also not making any changes to the existing CH_4 and N_2O standards. EPA is ~~also~~ extending the "0 g/mi upstream" ~~incentive~~ provision for electric vehicles beyond its current sunset of MY 2021, through MY 2026. EPA is also providing a 2.0 multiplier for dedicated and dual-fueled natural gas vehicles from MY2022-2026. The agencies are also making some improvements to the off-cycle credits program to provide streamlining, including adding certain technologies to the pre-approved technology menu. ~~Otherwise, compliance flexibilities in the two programs do not change significantly for the final rule.~~ These changes should help to streamline manufacturer use of those flexibilities in certain respects. Otherwise, compliance flexibilities in the two programs do not change significantly for the final rule. While manufacturers and suppliers sought a number of other additional compliance flexibilities, the agencies have concluded that the aforementioned existing flexibilities are reasonable and appropriate, and that additional flexibilities are not justified.

Commented [A12]: **CHANGE AS SHOWN:** Caveat needed because of the EPA extension of an incentive multiplier for natural gas vehicles for MY2022-2026 and the EPA extension of the zero grams/mile approach for electrified vehicles are not real-world improvements. Other edits in this paragraph are for factual corrections to the EPA GHG program.

[Text Forthcoming]

Table I-1Table I-1 and Table I-2Table I-2 present the total costs (technology and social), benefits, and net benefits for NHTSA's 2021-2027 preferred alternative CAFE and CO_2 levels, relative to the MY 2022-2025 augural standards and current MY 2021 standard. The preferred alternative exhibits a stringency rate increase of 1.5 percent per year for both passenger cars and light trucks. The values in Table I-1Table I-1 and Table I-2Table I-2 display (in total and annualized forms) costs for all MY 1975-2029 vehicles, and the benefits and net benefits represent the impacts of the standards over the full lifetimes of the vehicles sold or projected to be sold during model years 1975-2029.

Commented [A13]: REVISE: This is a little confusing – is Table I-2 regarding the EPA CO2 standards? If yes, that should be clarified in this sentence, as it is currently written as the NHTSA CAFE and NHTSA CO2 levels.

Commented [A14]: REVISE: Confirm whether this is correct based on final CO2 standard coefficients established in the SAFE FRM.

For this rulemaking, the baseline for cost and benefit reporting for NHTSA's CAFE program is the augural standards for MYs 2022-2026 and the existing standard for MY 2021. For EPA's CO_2 program, the baseline is the ~~currently final~~ MYs 2021-2025 standards and EPA program provisions adopted in the 2012 rule.

For this analysis, negative signs are used for changes in costs or benefits that decrease from those that would have resulted from the augural standards for MY 2022-2026 or the previously existing standard for MY 2021. Any changes that would increase either costs or benefits are shown as positive changes. Thus, an alternative that decreases both costs and benefits, will show declines (i.e., a negative sign) in both categories. From Table I-1Table I-1 and Table I-2Table I-2, the preferred alternative (Alternative 3) is estimated to decrease costs relative to the augural baseline by from $182 to $279 billion over the lifetime of MYs 1975-2029 passenger vehicles (range determined by discount rate across both CAFE and CO_2 programs). It will also decrease benefits from $188 to $314 billion over the life of these MY fleets. The net impact will be from a decrease of ~~from~~ $41 billion to an increase of $2 billion in total net benefits to society over this roughly 45-year timeframe. Annualized, this amounts to roughly $xx - $xx billion per year.

Commented [A15]: REVISE: This (and similar language below) is CAFE baseline only, and does not reflect EPA CO2 existing standards.

Table I-1 - Estimated 1975-2029 Model Year Costs, Benefits, and Net Benefits under the Preferred Alternative, CAFE

Cumulative Across MYs 1975-2029				
	Totals		**Annualized**	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Costs	-279.6	-200.3		
Benefits	-314.0	-197.9		
Net Benefits	-34.4	2.3		

Table I-2 - Estimated 1975-2029 Model Year Costs, Benefits, and Net Benefits under the Preferred Alternative, CO_2

Cumulative Across MYs 1975-2029

	Totals		Annualized	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Costs	-258.4	-182.9		
Benefits	-299.6	-188.7		
Net Benefits	-41.3	-5.8		

Table I-3Table I-3 and Table I-4Table I-4 lists costs, benefits, and net benefits for all seven alternatives that were examined.

Table I-3 – Total Costs, Benefits, and Net Benefits Passenger Cars and Light Trucks, MYs 1975-2029, I Standards

Alt	MYs	Stringency of Rate Increase	3% Discount Rate			7% Discount Rate		
			Costs	Benefits	Net Benefits	Costs	Benefits	Net Benefits
1	2021-2026	0.0%/Year PC, 0.0%/Year LT	-329.1	-370.8	-41.7	-234.6	-232.5	2.1
2	2021-2026	0.5%/Year PC, 0.5%/Year LT	-322.0	-362.9	-40.8	-229.5	-227.4	2.0
3	2021-2027	1.5%/Year PC, 1.5%/Year LT	-279.6	-314.0	-34.4	-200.3	-197.9	2.3
4	2021-2026	1.0%/Year PC, 2.0%/Year LT	-268.7	-298.0	-29.2	-192.7	-187.8	4.9
5	2022-2026	1.0%/Year PC, 2.0%/Year LT	-195.4	-211.9	-16.5	-139.3	-132.3	6.9
6	2021-2026	2.0%/Year PC, 3.0%/Year LT	-188.3	-201.9	-13.6	-135.9	-127.5	8.3
7	2022-2026	2.0%/Year PC, 3.0%/Year LT	-130.4	-140.2	-9.9	-94.0	-87.9	6.1

Table I-4 – Total Costs, Benefits, and Net Benefits Passenger Cars and Light Trucks, MYs 1975-2029, CO_2 Standards

Alt	MYs	Stringency of Rate Increase	3% Discount Rate			7% Discount Rate		
			Costs	Benefits	Net Benefits	Costs	Benefits	Net Benefits
1	2021-2026	0.0%/Year PC, 0.0%/Year LT	-314.8	-369.7	-54.8	-221.2	-231.6	-10.4
2	2021-2026	0.5%/Year PC, 0.5%/Year LT	-305.5	-358.3	-52.8	-214.9	-224.6	-9.7
3	2021-2027	1.5%/Year PC, 1.5%/Year LT	-258.4	-299.6	-41.3	-182.9	-188.7	-5.8

4	2021-2026	1.0%/Year PC, 2.0%/Year LT	-246.2	-285.5	-39.3	-174.2	-179.6	-5.4
5	2022-2026	1.0%/Year PC, 2.0%/Year LT	-180.3	-206.4	-26.1	-127.3	-129.5	-2.2
6	2021-2026	2.0%/Year PC, 3.0%/Year LT	-180.4	-206.9	-26.5	-129.2	-131.5	-2.3
7	2022-2026	2.0%/Year PC, 3.0%/Year LT	-123.3	-139.3	-16.0	-88.3	-89.1	-0.9

Table Table I-5Table I-5 and Table I-6Table I-6 show a summary of various impacts of the preferred alternative for CAFE and CO_2 standards. Impacts are presented in monetized and non-monetized values, as well as from the perspective of society and the consumer.

Table I-5 - Summary of Impacts for the Preferred Alternative (1.5%/Year PC, 1.5%/Year LT), CAFE Standards

Category	Light Truck	Passenger Car	Combined Fleet
Required MPG for MY 2030	34.1	47.7	40.5
Achieved MPG for MY 2030	36.0	50.3	42.7
Achieved MPG for MY 2020	31.9	44.2	37.5
Per Vehicle Price Increase	-$1,360	-$823	-$1,083
MY 2030 Lifetime Fuel Savings (per vehicle), Discounted at 3%	-$2,046	-$1,181	-$1,423
MY 2030 Lifetime Fuel Savings (per vehicle), Discounted at 7%	-$1,580	-$927	-$1,110
Consumer Per Vehicle Savings, Discounted at 3%	-$903	-$577	-$499
Consumer Per Vehicle Savings, Discounted at 7%	-$343	-$253	-$110
Payback Period Relative to MY 2017 (Years), Values Discounted at 3%	5	6	6
Payback Period Relative to MY 2017 (Years), Values Discounted at 7%	6	8	7
Total Lifetime Fuel Savings (bGallons)	-38	-46	-84
Total Lifetime CO_2 Reductions (million metric tons)	-409	-514	-923
Vehicle Safety-related Fatalities (Excluding Rebound Miles)	-2,349	1,875	-474
Vehicle Safety-related Fatalities (Rebound Miles)	-3,735	525	-3,210
Total Technology Costs ($b), Discounted at 3%	-$85	-$41	-$126
Total Technology Costs ($b), Discounted at 7%	-$68	-$32	-$101
Total Net Societal Benefits ($b), Discounted at 3%	$108	-$142	-$34
Total Net Societal Benefits ($b), Discounted at 7%	$82	-$80	$2

Commented [A16]: REVISE: It should be noted that these two rows are vehicle crash-related Fatalities, and not health impact related fatalities which will presumably be discussed in Section VII. For a more complete presentation of Fatalities associated with the final standards, EPA recommends the health impacts-related premature mortality estimates should be included in this table.

Table I-6 - Summary of Impacts for the Preferred Alternative (1.5%/Year PC, 1.5%/Year LT), CO_2 Standards

Category	Light Truck	Passenger Car	Combined Fleet

Required CO_2 for MY 2030 (g/mi)	243	168	202
Achieved CO_2 for MY 2030 (g/mi)	236	166	197
Per Vehicle Price Increase	-$1,098	-$856	-$977
MY 2030 Lifetime Fuel Savings (per vehicle), Discounted at 3%	-$1,948	-$1,392	-$1,461
MY 2030 Lifetime Fuel Savings (per vehicle), Discounted at 7%	-$1,504	-$1,096	-$1,143
Consumer Per Vehicle Savings, Discounted at 3%	-$1,205	-$708	-$678
Consumer Per Vehicle Savings, Discounted at 7%	-$647	-$351	-$280
Payback Period Relative to MY 2017 (Years), Values Discounted at 3%	5	5	5
Payback Period Relative to MY 2017 (Years), Values Discounted at 7%	6	7	7
Total Lifetime Fuel Savings (bGallons)	-31	-47.3	-78
Total Lifetime CO_2 Reductions (million metric tons)	-342	-525	-867
Vehicle Safety-related Fatalities (Excluding Rebound Miles)	-2,235	1,763	-471
Vehicle Safety-related Fatalities (Rebound Miles)	-3,626	460	-3,166
Total Technology Costs ($b), Discounted at 3%	-$65	-$43	-$108
Total Technology Costs ($b), Discounted at 7%	-$53	-$34	-$86
Total Net Societal Benefits ($b), Discounted at 3%	$91	-$65	-$41
Total Net Societal Benefits ($b), Discounted at 7%	$68	-$74	-$6

Commented [A17]: **REVISE:** It should be noted that these two rows are projected vehicle crash-related Fatalities, and not health impact related fatalities from the projected impacts of the SAFE final rule on air quality, which will presumably be discussed in Section VII. For a more complete presentation of the projected impacts of the SAFE final rule on fatalities, the air pollution health impacts-related premature mortality estimates should be included in this table.

The agencies note that the NPRM drew more public comments (and, particularly, more pages of substantive comments) than any rulemaking in the history of the CAFE or CO_2 tailpipe emissions programs—exceeding 750,000 comments. The agencies recognized in the NPRM that the proposal was significantly different from the final rules set forth in 2012, and explained at length the reasons for those differences—namely, that new information and considerations, along with an expanded and updated analysis, and EPA's different balancing of statutory factors had led to different tentative conclusions. Today's final rules represent a further evolution of the work that supported the proposal, based on improved quantitative methodology and in careful consideration of the hundreds of thousands of public comments and deep reflection on the serious issues before the agencies. Simply put, the agencies have heard the comments, and today's analysis and decision reflect the agencies' grappling with the issues commenters raised, as well as all of the other information before the agencies. These programs and issues are weighty, and the agencies believe that a reasonable balance has been struck in these final rules between the many competing national needs that these regulatory programs collectively address.

Commented [A18]: CHANGE AS SHOWN: This is consistent with EPA's justification of the CO2 standards in Section 9

II. Overview of final rule

[Text Forthcoming]

III. Purpose of the rule

The Administrative Procedure Act (APA) requires agencies to incorporate in their final rules a "concise general statement of their basis and purpose."[13] While the entire preamble document represents the agencies' overall explanation of the basis and purpose for this regulatory action, this section within the preamble is intended ~~as a direct~~ specifically to ~~response to~~address ~~that~~ the APA (and related CAA) requirements. Executive Order 12866 further states that "Federal agencies should promulgate only such regulations as are required by law, are necessary to interpret the law, or are made necessary by compelling public need, such as material failures of private markets to protect or improve the health and safety of the public, the environment, or the well-being of the American people."[14] Section VI[on sales] discusses at greater length the question of whether a market failure exists that these final rules may address.

NHTSA and EPA are legally obligated to set CAFE and ~~CO_2~~ GHG standards, respectively, and do not have the authority to decline to regulate.[15] The agencies are issuing these final rules to fulfill their respective statutory obligations to provide maximum feasible fuel economy standards and limit emissions of pollutants from new motor vehicles which have been found to endanger public health and welfare (in this case, specifically carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs)). Continued progress in meeting these statutory obligations is both legally necessary and good for America – greater energy security and reduced emissions protect the American public.

The final standards, as compared to the proposal which would have maintained standards at MY 2020 levels through MY 2026, are projected to reduce fuel consumption by [xxx] billion gallons over [xxx], and to reduce CO_2 emissions by [xxx] million metric tons over some amount of time.

As explained above, these final rules set ~~for some years or~~ amend~~s~~ fuel economy and carbon dioxide standards for model years 2021-2026. Many commenters argued that it was not appropriate to amend previously-established CO_2 and CAFE standards, generally because those commenters believed that the administrative record established for the 2012 final rule and EPA's January 2017 Final Determination was superior to the record that informed the NPRM, and that that prior record led necessarily to the policy conclusion that the previously-established standards should remain in place.[16] Some commenters similarly argued that EPA's Revised Final Determination – which~~, for EPA,~~ preceded this regulatory action – was invalid because, ~~those commenters~~they allege, it did not follow the procedures established for the mid-term evaluation

Commented [A19]: REVISE: EPA has already set N2O and methane standards and is not revising them in this final rule.

Commented [A20]: REVISE: This statement is not correct for the EPA CO2 standards, as the standards EPA is finalizing in the SAFE rule result in increased emissions relative to the previous EPA standards being replaced by the SAFE final rule.

Commented [A21]: CHANGE AS SHOWN: Edits for clarity of EPA's program in this and following paragraphs.

[13] 5 U.S.C. 553(c); see also Clean Air Act (CAA) section 307(d)(6)(A), 42 U.S.C. 7607(d)(6)(A).
[14] EO 12866, Section 1(a).
[15] For CAFE, *see* 49 U.S.C. 32902; for CO_2, *see* 42 U.S.C. 7521(a).
[16] Comments arguing that the prior record was superior to the current record, and thus a better basis for decision-making, will be addressed throughout the balance of this preamble.

that EPA codified into regulation,[17] and also because the Revised Final Determination was not based on the prior record.[18]

The agencies considered a range of alternatives in the proposal, including the baseline/no action alternative of retaining the existing EPA carbon dioxide standards. As the agencies explained in the proposal, the proposal was entirely *de novo*, based on an entirely new analysis reflecting the best and most up-to-date information available to the agencies.[19] This rulemaking action is separate and distinct from the EPA's Revised Final Determination, which ~~did not reflect~~ itself was neither a proposed nor a final decision that the standards "must" be revised. EPA retained full discretion in this rulemaking to revise the standards or not revise them. In any addition ~~event~~, the case law is clear that agencies are free to reconsider their prior decisions.[20] With that legal principle in mind, we agree with commenters that the amended (and ~~the~~ new) CO_2 and CAFE standards must be consistent with the CAA and ~~with~~ EPCA/EISA, respectively, and this preamble and the accompanying FRIA explain in detail why the agencies believe they are consistent. The section below discusses briefly the authority given to the agencies by their respective governing statutes, and the factors that Congress directed the agencies to consider as they exercise that authority in pursuit of fulfilling their statutory obligations.

A. EPA's statutory requirements

EPA is setting national CO_2 standards for passenger cars and light trucks under Section 202(a) of the Clean Air Act (CAA).[21] ~~and under its authority to measure passenger car and light truck fleet fuel economy pursuant to the Energy Policy and Conservation Act (EPCA).~~[22] Section 202(a) of the CAA requires EPA to establish standards for emissions of pollutants from new motor vehicles which ~~emissions~~ cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare.[23] In establishing such standards, EPA ~~must~~

Commented [A22]: CHANGE AS SHOWN: EPA's EPCA authority on testing for CAFE standards is not relevant to our setting of CO2 standards.

[17] 40 CFR 86.1818-12(h).

[18] *See, e.g.*, comments from the States and Cities, Attachment 1, Docket No. NHTSA-2018-0067-11735, at 40-42; CARB, Detailed Comments, Docket No. NHTSA-2018-0067-11873, at 71-72; CBD *et. al*, Appendix A, Docket No. NHTSA-2018-0067-12000, at 214-228.

[19] 83 FR 42968, 42987 (Aug. 24, 2018).

[20] *See, e.g.*, Encino Motorcars, LLC v. Navarro, 136 S. Ct. 2117, 2125 (2016) ("Agencies are free to change their existing policies as long as they provide a reasoned explanation for the change."); FCC v. Fox Television Stations, Inc., 556 U.S. 502, 515 (2009) (When an agency changes its existing position, it "need not always provide a more detailed justification than what would suffice for a new policy created on a blank slate. Sometimes it must – when, for example, its new policy rests on factual findings that contradict those which underlay its prior policy; or when its prior policy has engendered serious reliance interests that must be taken into account….In such cases it is not that further justification is demanded by the mere fact of policy change, but that a reasoned explanation is needed for disregarding facts and circumstances that underlay or were engendered by the prior policy.")

[21] 42 U.S.C. 7521(a).

[22] ~~49 U.S.C. 32904(c).~~

[23] *See* Coalition for Responsible Regulation v. EPA, 684 F.3d 102, 114-115 (D.C. Cir. 2012) ("'If EPA makes a finding of endangerment, the Clean Air Act requires the [a]gency to regulate emissions of the deleterious pollutant from new motor vehicles. …Given the non-discretionary duty in Section 202(a)(1) and the limited flexibility available under Section 202(a)(2), which this court has held related only to the motor vehicle industry, …EPA had no statutory basis on which it could ground [any] reasons for further inaction'") (quoting *Massachusetts v. EPA*, 549 U.S. 497, 533-35 (2007).

considers issues of technological~~ical~~ feasibility, cost, ~~and~~ available lead time, and other factors. Standards under Section 202(a) thus take effect only after providing "such period as the Administrator finds necessary to permit the development and application of the requisite technology, giving appropriate consideration to the cost of compliance within such period."[24] EPA's statutory requirements are further discussed in Section VIII.A.

Commented [A23]: DELETE: EPA discussion of statutory requirements is contained in Section VIII.A.

~~1. History of EPA's regulation of vehicle emissions~~

~~[Text Forthcoming]~~

~~2. Massachusetts v. EPA and EPA's Endangerment Finding~~

~~[Text Forthcoming]~~

~~3. Statutory differences in the way EPA regulates criteria pollutant emissions from vehicles and CO_2 emissions from vehicles~~

~~[Text Forthcoming]~~

B. NHTSA's statutory requirements

NHTSA is setting national Corporate Average Fuel Economy (CAFE) standards for passenger cars and light trucks for each model year as required under EPCA, as amended by EISA.[25] EPCA mandates a motor vehicle fuel economy regulatory program that balances statutory factors in setting minimum fuel economy standards to facilitate energy conservation. EPCA allocates the responsibility for implementing the program between NHTSA and EPA as follows: NHTSA sets CAFE standards for passenger cars and light trucks; EPA establishes the procedures for testing, tests vehicles, collects and analyzes manufacturers' data, and calculates the individual and average fuel economy of each manufacturer's passenger cars and light trucks; and NHTSA enforces the standards based on EPA's calculations.

The following sections enumerate specific statutory requirements for NHTSA in setting CAFE standards and NHTSA's interpretations of them, where applicable. Many comments were received on these requirements and interpretations. Because this is intended as an overview section, those comments will be addressed below in Section VIII rather than here, and we refer readers to that part of the document for more information.

For each future model year, EPCA (as amended by EISA) requires that DOT (by delegation, NHTSA) establish separate passenger car and light truck standards at "the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year,"[26] based on the agency's consideration of four statutory factors: "technological

[24] 42 U.S.C. 7521(a)(2).
[25] EPCA and EISA direct the Secretary of Transportation to develop, implement, and enforce fuel economy standards (*see* 49 U.S.C. 32901 *et. seq.*), which authority the Secretary has delegated to NHTSA at 49 CFR 1.94(c).
[26] 49 U.S.C. 32902(a) and (b).

feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy."[27] The law also allows NHTSA to amend standards that are already in place, as long as doing so meets these requirements.[28] EPCA does not define these terms or specify what weight to give each concern in balancing them; thus, NHTSA defines them and determines the appropriate weighting that leads to the maximum feasible standards given the circumstances in each CAFE standard rulemaking.[29]

EISA added several other requirements to the setting of separate passenger car and light truck standards. Standards must be "based on 1 or more vehicle attributes related to fuel economy and express[ed] ... in the form of a mathematical function."[30] New standards must also be set at least 18 months before the model year in question, as would amendments to increase standards previously set.[31] NHTSA must regulations prescribing average fuel economy standards for at least 1, but not more than 5, model years at a time.[32] A number of comments addressed these requirements; for the reader's reference, those comments will be summarized and responded to in Section VIII. EISA also added the requirement that NHTSA set a minimum standard for domestically-manufactured passenger cars,[33] which will also be discussed further in Section VIII below.

For MYs 2011-2020, EISA further required that the separate standards for passenger cars and for light trucks be set at levels high enough to ensure that the achieved average fuel economy for the entire industry-wide combined fleet of new passenger cars and light trucks reach at least 35 mpg not later than MY 2020, and standards for those years were also required to "increase ratably."[34] For model years after 2020, standards must be set at the maximum feasible level.[35]

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[27] 49 U.S.C. 32902(f).
[28] 49 U.S.C. 32902(g).
[29] *See* Center for Biological Diversity v. NHTSA, 538 F.3d 1172, 1195 (9th Cir. 2008) (hereafter "*CBD v. NHTSA*") ("The EPCA clearly requires the agency to consider these four factors, but it gives NHTSA discretion to decide how to balance the statutory factors – as long as NHTSA's balancing does not undermine the fundamental purpose of the EPCA: energy conservation.")
[30] 49 U.S.C. 32902(b)(3)(A).
[31] 49 U.S.C. 32902(a), (g)(2).
[32] 49 U.S.C. 39202(b)(3)(B).
[33] 49 U.S.C. 32902(b)(4).
[34] 49 U.S.C. 32902(b)(2)(A) and (C). NHTSA has CAFE standards in place that are projected to result in industry-achieved fuel economy levels over 35 mpg in MY 2020. EPA typically provides verified final CAFE data from manufacturers to NHTSA several months or longer after the close of the MY in question, so the actual MY 2020 fuel economy will not be known until well after MY 2020 has ended. The standards for all MYs up to and including 2020 are known and not at issue in this regulatory action, so these provisions are noted for completeness rather than immediate relevance to this final rule. Because neither of these requirements apply after MY 2020, they are not relevant to this rulemaking and will not be discussed further.
[35] 49 U.S.C. 32902(b)(2)(B).

1. Factors that must be considered in deciding what levels of CAFE standards are "maximum feasible"

a) Technological feasibility

"Technological feasibility" refers to whether a particular method of improving fuel economy can be available for commercial application in the model year for which a standard is being established. Thus, in determining the level of new standards, the agency is not limited to technology that is already being commercially applied at the time of the rulemaking. For this rulemaking, NHTSA has evaluated and considered all types of technologies that improve real-world fuel economy, although not every possible technology was expressly included in the analysis, as discussed in Section VI and also in Section VIII.

b) Economic practicability

"Economic practicability" refers to whether a standard is one "within the financial capability of the industry, but not so stringent as to" lead to "adverse economic consequences, such as a significant loss of jobs or the unreasonable elimination of consumer choice."[36] The agency has explained in the past that this factor can be especially important during rulemakings in which the automobile industry is facing significantly adverse economic conditions (with corresponding risks to jobs). Economic practicability is a broad factor that includes considerations of the uncertainty surrounding future market conditions and consumer demand for fuel economy in addition to other vehicle attributes.[37] In an attempt to evaluate the economic practicability of different future levels of CAFE standards (i.e., the regulatory alternatives considered in this rulemaking), NHTSA considers a variety of factors, including the annual rate at which manufacturers can increase the percentage of their fleet(s) that employ a particular type of fuel-saving technology, the specific fleet mixes of different manufacturers, assumptions about the cost of the standards to consumers, and consumers' valuation of fuel economy, among other things, including, in part, safety.

It is important to note, however, that the law does not preclude a CAFE standard that poses considerable challenges to any individual manufacturer. The Conference Report for EPCA, as enacted in 1975, makes clear, and the case law affirms, "a determination of maximum feasible average fuel economy should not be keyed to the single manufacturer which might have the most difficulty achieving a given level of average fuel economy."[38] Instead, NHTSA is compelled "to weigh the benefits to the nation of a higher fuel economy standard against the difficulties of individual automobile manufacturers."[39] Accordingly, while the law permits NHTSA to set CAFE standards that exceed the projected capability of a particular manufacturer

[36] 67 FR 77015, 77021 (Dec. 16, 2002).
[37] *See, e.g.*, Center for Auto Safety v. NHTSA ("CAS"), 793 F.2d 1322 (D.C. Cir. 1986) (Administrator's consideration of market demand as component of economic practicability found to be reasonable); Public Citizen v. NHTSA, 848 F.2d 256 (D.C. Cir. 1988) (Congress established broad guidelines in the fuel economy statute; agency's decision to set lower standard was a reasonable accommodation of conflicting policies).
[38] Center for Auto Safety v. NHTSA ("CAS"), 793 F.2d 1322, 1352 (D.C. Cir. 1986).
[39] *Id.*

as long as the standard is economically practicable for the industry as a whole, the agency cannot simply disregard that impact on individual manufacturers.[40] That said, in setting fuel economy standards, NHTSA does not seek to maintain competitive positions among the industry players, and notes that while a particular CAFE standard may pose difficulties for one manufacturer as being too high or too low, it may also present opportunities for another. NHTSA has long held that the CAFE program is not necessarily intended to maintain the competitive positioning of each particular company. Rather, it is intended to enhance the fuel economy of the vehicle fleet on American roads, while protecting motor vehicle safety and paying close attention to the economic risks.

c) The effect of other motor vehicle standards of the Government on fuel economy

"The effect of other motor vehicle standards of the Government on fuel economy" involves an analysis of the effects of compliance with emission, safety, noise, or damageability standards on fuel economy capability and thus on average fuel economy. In many past CAFE rulemakings, NHTSA has said that it considers the adverse effects of other motor vehicle standards on fuel economy. It said so because, from the CAFE program's earliest years,[41] the effects of such compliance on fuel economy capability over the history of the program have been negative ones. For example, safety standards that have the effect of increasing vehicle weight lower vehicle fuel economy capability and thus decrease the level of average fuel economy that the agency can determine to be feasible. NHTSA has considered the additional weight that it estimates would be added in response to new safety standards during the rulemaking timeframe.[42] NHTSA has also accounted for EPA's "Tier 3" standards for criteria pollutants in its estimates of technology effectiveness.[43]

The NPRM also discussed how EPA's CO_2 standards for light-duty vehicles and California's Advanced Clean Cars program fit into NHTSA's consideration of "the effect of other motor vehicle standards of the Government on fuel economy." We note that on September 19, 2019, to ensure One National Program for automobile fuel economy and carbon dioxide emissions standards, the agencies finalized regulatory text related to preemption of State tailpipe CO_2 standards and Zero Emission Vehicle (ZEV) mandates under EPCA and partial withdrawal of a waiver previously provided to California under the Clean Air Act.[44] This final rule's impact on State programs – including California's – will therefore be somewhat different from the NPRM's consideration. In the interest of brevity, this preamble will hold further discussion of that point, along with responses to comments received, until Section VIII.

[40] *Id.* ("...the Secretary must weigh the benefits to the nation of a higher average fuel economy standard against the difficulties of individual automobile manufacturers.")
[41] 42 FR 63184, 63188 (Dec. 15, 1977). *See also* 42 FR 33534, 33537 (Jun. 30, 1977).
[42] FRIA, Ch. [xxx].
[43] FRIA, Ch. [xxx].
[44] 84 FR 51310 (Sept. 27, 2019).

d) The need of the United States to conserve energy

"The need of the United States to conserve energy" means "the consumer cost, national balance of payments, environmental, and foreign policy implications of our need for large quantities of petroleum, especially imported petroleum."[45] Environmental implications principally include changes in emissions of carbon dioxide and criteria pollutants and air toxics. Prime examples of foreign policy implications are energy independence and security concerns.

(1) Consumer costs and fuel prices

Fuel for vehicles costs money for vehicle owners and operators. All else equal (and this is an important qualification), consumers benefit from vehicles that need less fuel to perform the same amount of work. Future fuel prices are a critical input into the economic analysis of potential CAFE standards because they determine the value of fuel savings both to new vehicle buyers and to society, the amount of fuel economy that the new vehicle market is likely to demand in the absence of new standards, and they inform NHTSA about the consumer cost of our need for large quantities of petroleum. In this final rule, NHTSA's analysis relies on fuel price projections estimated using the version of NEMS used for the U.S. Energy Information Administration's (EIA) Annual Energy Outlook for 2019.[46] Federal government agencies generally use EIA's price projections in their assessment of future energy-related policies.

(2) National balance of payments

Historically, the need of the United States to conserve energy has included consideration of the "national balance of payments" because of concerns that importing large amounts of oil created a significant wealth transfer to oil-exporting countries and left the U.S. economically vulnerable.[47] As recently as 2009, nearly half of the U.S. trade deficit was driven by petroleum,[48] yet this concern has largely lain fallow in more recent CAFE actions, in part because other factors besides petroleum consumption have since played a bigger role in the U.S. trade deficit.[49] Given significant recent increases in U.S. oil production and corresponding

[45] 42 FR 63184, 63188 (1977).

[46] The analysis for the proposal relied on fuel price projections from AEO 2017; the difference in the projections is discussed in Section VI.

[47] *See, e.g.*, 42 FR 63184, 63192 (Dec. 15, 1977) ("A major reason for this need [to reduce petroleum consumption] is that the importation of large quantities of petroleum creates serious balance of payments and foreign policy problems. The United States currently spends approximately $45 billion annually for imported petroleum. But for this large expenditure, the current large U.S. trade deficit would be a surplus.")

[48] *See* "Today in Energy: Recent improvements in petroleum trade balance mitigate U.S. trade deficit," U.S. Energy Information Administration (Jul. 21, 2014), *available at* https://www.eia.gov/todayinenergy/detail.php?id=17191.

[49] *See, e.g.*, Nida Çakir Melek and Jun Nie, "What Could Resurging U.S. Energy Production Mean for the U.S. Trade Deficit," Mar. 7, 2018, Federal Reserve Bank of Kansas City. *Available at* https://www.kansascityfed.org/publications/research/mb/articles/2018/what-could-resurging-energy-production-mean. The authors state that "The decline in U.S. net energy imports has prevented the total U.S. trade deficit from widening further. ...In 2006, petroleum accounted for about 16 percent of U.S. goods imports and about 3 percent of U.S. goods exports. By the end of 2017, the share of petroleum in total goods imports declined to 8 percent, while the share in total goods exports almost tripled, shrinking the U.S. petroleum trade deficit. Had the petroleum trade

decreases in oil imports, this concern seems likely to remain fallow for the foreseeable future.[50] Increasingly, changes in the price of fuel have come to represent transfers between domestic consumers of fuel and domestic producers of petroleum rather than gains or losses to foreign entities.

As flagged in the NPRM, some commenters raised concerns about potential economic consequences for automaker and supplier operations in the U.S. due to disparities between CAFE standards at home and their counterpart fuel economy/efficiency and CO_2 standards abroad. NHTSA finds these concerns more relevant to technological feasibility and economic practicability considerations than to the national balance of payments. The discussion in Section VIII below addresses this topic in more detail.

(3) Environmental implications

Higher fleet fuel economy can reduce U.S. emissions of various pollutants by reducing the amount of oil that is produced and refined for the U.S. vehicle fleet, but can also increase emissions by reducing the cost of driving, which can result in more vehicle miles traveled (*i.e.*, the rebound effect). Thus, the net effect of more stringent CAFE standards on emissions of each pollutant depends on the relative magnitude of both its reduced emissions in fuel refining and distribution and increases in its emissions from vehicle use. Fuel savings from CAFE standards also necessarily results in lower emissions of CO_2, the main greenhouse gas emitted as a result of refining, distributing, and using transportation fuels. Reducing fuel consumption directly reduces CO_2 emissions because the primary source of transportation-related CO_2 emissions is fuel combustion in internal combustion engines.

NHTSA has considered environmental issues, both within the context of EPCA and the context of the National Environmental Policy Act (NEPA), in making decisions about the setting of standards since the earliest days of the CAFE program. As courts of appeal have noted in three decisions stretching over the last 20 years,[51] NHTSA defined "the need of the United States to conserve energy" in the late 1970s as including, among other things, environmental implications. In 1988, NHTSA included climate change concepts in its CAFE notices and

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deficit not improved, all else unchanged, the total U.S. trade deficit would likely have been more than 35 percent wider by the end of 2017."

[50] For an illustration of recent increases in U.S. production, *see, e.g.*, 'U.S. crude oil and liquid fuels production," Short-Term Energy Outlook, U.S. Energy Information Administration (Aug. 2019), *available at* http://www.eia.gov/outlooks/steo/images/Fig16.png. EIA noted in April 2019 that "Annual U.S. crude oil production reached a record level of 10.96 million barrels per day (b/d) in 2018, 1.6 million b/d (17%) higher than 2017 levels. In December 2018, monthly U.S. crude oil production reached 11.96 million b/d, the highest monthly level of crude oil production in U.S. history. U.S crude oil production has increased significantly over the past 10 years, driven mainly by production from tight rock formations using horizontal drilling and hydraulic fracturing. EIA projects that U.S. crude oil production will continue to grow in 2019 and 2020, averaging 12.3 million b/d and 13.0 million b/d, respectively." "Today in Energy: U.S. crude oil production grew 17% in 2018, surpassing the previous record in 1970," EIA, Apr. 9, 2019. *Available at* http://www.eia.gov/todayinenergy/detail.php?id=38992.

[51] *CAS*, 793 F.2d 1322, 1325 n. 12 (D.C. Cir. 1986); *Public Citizen*, 848 F.2d 256, 262-63 n. 27 (D.C. Cir 1988) (noting that "NHTSA itself has interpreted the factors it must consider in setting CAFE standards as including environmental effects"); *CBD*, 538 F.3d 1172 (9th Cir. 2007).

prepared its first environmental assessment addressing that subject.[52] It cited concerns about climate change as one of its reasons for limiting the extent of its reduction of the CAFE standard for MY 1989 passenger cars.[53] Since then, NHTSA has considered the effects of reducing tailpipe emissions of CO_2 in its fuel economy rulemakings pursuant to the need of the United States to conserve energy by reducing petroleum consumption.

(4) Foreign policy implications

U.S. consumption and imports of petroleum products can impose additional costs (*i.e.*, externalities) on the domestic economy that are not reflected in the market price for crude petroleum or in the prices paid by consumers for petroleum products such as gasoline. NHTSA has said previously that these costs can include (1) higher prices for petroleum products resulting from the effect of U.S. oil demand on world oil prices, (2) the risk of disruptions to the U.S. economy caused by sudden increases in the global price of oil and its resulting impact on fuel prices faced by U.S. consumers, and (3) expenses for maintaining the strategic petroleum reserve (SPR) to provide a response option should a disruption in commercial oil supplies threaten the U.S. economy, to allow the U.S. to meet part of its International Energy Agency obligation to maintain emergency oil stocks, and to provide a national defense fuel reserve.[54] Higher U.S. consumption of crude oil or refined petroleum products increases the magnitude of these external economic costs, thus increasing the true economic cost of supplying transportation fuels above the resource costs of producing them. Conversely, reducing U.S. consumption of crude oil or refined petroleum products (by reducing motor fuel use) can reduce these external costs.

While these costs are considerations, the United States has significantly increased oil production capabilities in recent years, to the extent that the U.S. is currently producing enough oil to satisfy nearly all of its energy needs and is projected to continue to do so (or even become a net energy exporter in the near future).[55] This has added stable new supply to the global oil market, which ameliorates the U.S.' need to conserve energy from a security perspective even given that oil is a global commodity. We discuss this issue in more detail in Section VIII below.

2. Factors that NHTSA is prohibited from considering

EPCA states that in determining the level at which it should set CAFE standards for a particular model year, NHTSA may not consider the ability of manufacturers to take advantage of several EPCA provisions that facilitate compliance with CAFE standards and thereby can reduce their costs of compliance.[56] As discussed further below, NHTSA cannot consider

[52] 53 FR 33080, 33096 (Aug. 29, 1988).
[53] 53 FR 39275, 39302 (Oct. 6, 1988).
[54] While the U.S. maintains a military presence in certain parts of the world to help secure global access to petroleum supplies, that is neither the primary nor the sole mission of U.S. forces overseas. Additionally, the scale of oil consumption reductions associated with CAFE standards would be insufficient to alter any existing military missions focused on ensuring the safe and expedient production and transportation of oil around the globe. See Chapter [xxx] of the FRIA for more information on this topic.
[55] *See* AEO 2019, at 14 ("In the Reference case, the United States becomes a net exporter of petroleum liquids after 2020 as U.S. crude oil production increases and domestic consumption of petroleum products decreases."). *Available at* https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf.
[56] 49 U.S.C. 32902(h).

compliance credits that manufacturers earn by exceeding the CAFE standards and then use to achieve compliance in years in which their measured average fuel economy falls below the standards. NHTSA also cannot consider the use of alternative fuels by dual-fueled vehicles (such as plug-in hybrid electric vehicles) nor the availability of dedicated alternative fuel vehicles (such as battery electric or hydrogen fuel cell vehicles) in any model year. EPCA encourages the production of alternative fuel vehicles by specifying that their fuel economy is to be determined using a special calculation procedure that results in those vehicles being assigned a higher fuel economy level than they actually achieve. For non-statutory incentives that NHTSA developed by regulation, NHTSA does not consider these incentives subject to the EPCA prohibition on considering flexibilities. These topics will be addressed further in Section VIII below.

3. Other considerations in determining maximum feasible CAFE standards

NHTSA historically has interpreted EPCA's statutory factors as including consideration for potential adverse safety consequences in setting CAFE standards. Courts have consistently recognized that this interpretation is reasonable. As courts have recognized, "NHTSA has always examined the safety consequences of the CAFE standards in its overall consideration of relevant factors since its earliest rulemaking under the CAFE program."[57] The courts have consistently upheld NHTSA's implementation of EPCA in this manner.[58] Thus, in evaluating what levels of stringency would result in maximum feasible standards, NHTSA assesses the potential safety impacts and considers them in balancing the statutory considerations and to determine the maximum feasible level of the standards.[59] Many commenters addressed the NPRM's analysis of safety impacts; those comments will be summarized and responded to in Section VI and also in each agency's discussion in Section VIII.

The above sections explain what Congress thought was important enough to codify when it directed each agency to regulate, and begin to explain how the agencies have interpreted those directions over time and in this final rule. The next section looks more closely at the interplay

[57] *Competitive Enterprise Institute v. NHTSA*, 901 F.2d 107, 120 n. 11 (D.C. Cir. 1990) ("*CEI-I*") (citing 42 Fed. Reg. 33534, 33551 (Jun. 30, 1977).

[58] *See, e.g.*, *Competitive Enterprise Institute v. NHTSA*, 956 F.2d 321, 322 (D.C. Cir. 1992) ("*CEI-II*") (in determining the maximum feasible fuel economy standard, "NHTSA has always taken passenger safety into account," citing *CEI-I*, 901 F.2d at 120 n. 11); *Competitive Enterprise Institute v. NHTSA*, 49 F.3d 481, 483-83 (D.C. Cir. 1995) (same); *Center for Biological Diversity v. NHTSA*, 538 F.3d 1172, 1203-04 (9th Cir. 2008) (upholding NHTSA's analysis of vehicle safety issues with weight in connection with the MYs 2008-2011 light truck CAFE rulemaking).

[59] NHTSA stated in the NPRM that "While we discuss safety as a separate consideration, NHTSA also considers safety as closely related to, and in some circumstances a subcomponent of, economic practicability. On a broad level, manufacturers have finite resources to invest in research and development. Investment into the development and implementation of fuel saving technology necessarily comes at the expense of investing in other areas such as safety technology. On a more direct level, when making decisions on how to equip vehicles, manufacturers must balance cost considerations to avoid pricing further consumers out of the market. As manufacturers add technology to increase fuel efficiency, they may decide against installing new safety equipment to reduce cost increases. And as the price of vehicles increase beyond the reach of more consumers, such consumers continue to drive or purchase older, less safe vehicles. In assessing practicability, NHTSA also considers the harm to the nation's economy caused by highway fatalities and injuries." 83 FR at 43209 (Aug. 24, 2018). Many comments were received on this issue, which will be discussed further in Section VIII below.

between Congress's direction to the agencies and the aspects of the market that these regulations affect, as follows.

IV. Purpose of analytical approach considered as part of decision-making

A. Relationship of analytical approach to governing law

Like the NPRM, today's final rule is supported by extensive analysis of potential impacts of the regulatory alternatives under consideration. Below, Section VI reviews the analytical approach, Section VII summarizes the results of the analysis, and Section VIII explains how the final standards—informed by this analysis—fulfill the agencies' statutory obligations. Accompanying today's notice, a final Regulatory Impact Analysis (FRIA) and, for NHTSA's consideration, a final Environmental Impact Analysis (FEIS), together provide a more extensive and detailed enumeration of related methods, estimates, assumptions, and results. The agencies' analysis has been constructed specifically to reflect various aspects of governing law applicable to CAFE and CO_2 standards, and has been expanded and improved in response to comments received to the NPRM and based on additional work by the agencies. The analysis aided the agencies in implementing their statutory obligations, including the weighing of competing considerations, by reasonably informing the agencies about the estimated effects of choosing different regulatory alternatives.

The agencies' analysis makes use of a range of data (i.e., observations of things that have occurred), estimates (i.e., things that may occur in the future), and models (i.e., methods for making estimates). Two examples of *data* include (1) records of actual odometer readings used to estimate annual mileage accumulation at different vehicle ages and (2) CAFE compliance data used as the foundation for the "analysis fleet" containing, among other things, production volumes and fuel economy levels of specific configurations of specific vehicle models produced for sale in the U.S. Two examples of *estimates* include (1) forecasts of future GDP growth used, with other estimates, to forecast future vehicle sales volumes and (2) the "retail price equivalent" (RPE) factor used to estimate the ultimate cost to consumers of a given fuel-saving technology, given accompanying estimates of the technology's "direct cost," as adjusted to account for estimated "cost learning effects."

The agencies' analysis makes use of several models, some of which are actually integrated systems of multiple models. As discussed in the NPRM, the agencies' analysis of CAFE and CO_2 standards involves two basic elements: first, estimating ways each manufacturer could potentially respond to a given set of standards in a manner that considers potential consumer response; and second, estimating various impacts of those responses. Estimating manufacturers' potential responses involves simulating manufacturers' decision-making processes regarding the year-by-year application of fuel-saving technologies to specific vehicles. Estimating impacts involves calculating resultant changes in new vehicle costs, estimating a variety of costs (e.g., for fuel) and effects (e.g., CO_2 emissions from fuel combustion) occurring as vehicles are driven over their lifetimes before eventually being scrapped, and estimating the monetary value of these effects. Estimating impacts also involves consideration of the response of consumers—e.g., whether consumers will purchase the vehicles and in what quantities. Both of these basic analytical elements involve the application of many analytical inputs.

The agencies' analysis uses the CAFE Model to estimate manufacturers' potential responses to new CAFE and CO_2 standards and to estimate various impacts of those responses. The model may be characterized as an integrated system of models. For example, one model estimates manufacturers' responses, another estimates resultant changes in total vehicle sales, and still another estimates resultant changes in fleet turnover (i.e., scrappage). The CAFE model makes use of many inputs, values of which are developed *outside* of the model and not *by* the model. For example, the model applies fuel prices; it does not estimate fuel prices. The model does not determine the form or stringency of the standards; instead, the model applies inputs specifying the form and stringency of standards to be analyzed and produces outputs showing effects of manufacturers working to meet those standards, which become the basis for comparing between different potential stringencies.

The agencies also use EPA's MOVES model to estimate "tailpipe" (a.k.a. "vehicle" or "downstream") emission factors for criteria pollutants,[60] and use four DOE and DOE-sponsored models to develop inputs to the CAFE model, including three developed and maintained by DOE's Argonne National Laboratory. The agencies use the DOE Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) to estimate fuel prices,[61] and use Argonne's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model to estimate emissions rates from fuel production and distribution processes.[62] DOT also sponsored DOE/Argonne to use Argonne's Autonomie full-vehicle modeling and simulation system to estimate the fuel economy impacts for roughly a million combinations of technologies and vehicle types.[63, 64] Section VI, below, and the accompanying final RIA document details of the agencies' use of these models. In addition, as discussed in the final EIS accompanying today's notice, DOT relied on a range of climate and photochemical models to estimate impacts on climate, air quality, and public health. The EIS discusses and documents the use of these models.

As further explained in the NPRM,[65] to prepare for analysis supporting the proposal, DOT expanded the CAFE model to address EPA statutory and regulatory requirements through a

[60] *See* https://www.epa.gov/moves. Today's final rule used version MOVES2014b, *available at* https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves.
[61] *See* https://www.eia.gov/outlooks/aeo/info_nems_archive.php. Today's final rule uses fuel prices estimated using the Annual Energy Outlook (AEO) 2019 version of NEMS (*see* https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2019&cases=ref2019&sourcekey=0).
[62] Information regarding GREET is available at https://greet.es.anl.gov/index.php. Today's notice uses the 2018 version of GREET.
[63] As part of the Argonne simulation effort, individual technology combinations simulated in Autonomie were paired with Argonne's BatPAC model to estimate the battery cost associated with each technology combination based on characteristics of the simulated vehicle and its level of electrification. Information regarding Argonne's BatPAC model is available at http://www.cse.anl.gov/batpac/.
[64] In addition, the impact of engine technologies on fuel consumption, torque, and other metrics was characterized using GT POWER simulation modeling in combination with other engine modeling that was conducted by IAV Automotive Engineering, Inc. (IAV). The engine characterization "maps" resulting from this analysis were used as inputs for the Autonomie full-vehicle simulation modeling. Information regarding GT Power is available at https://www.gtisoft.com/gt-suite-applications/propulsion-systems/gt-power-engine-simulation-software.
[65] 83 FR 42986, 43003 (Aug. 24, 2018).

year-by-year simulation of how manufacturers could comply with EPA's CO_2 standards, including:

- Calculation of vehicle models' CO_2 emission rates before and after application of fuel-saving (and, therefore, CO_2-reducing) technologies;
- Calculation of manufacturers' fleet average CO_2 emission rates;
- Calculation of manufacturers' fleet average CO_2 emission rates under attribute-based CO_2 standards;
- Accounting for adjustments to average CO_2 emission rates reflecting reduction of air conditioner refrigerant leakage;
- Accounting for the treatment of alternative fuel vehicles for CO_2 compliance;
- Accounting for production "multipliers" for PHEVs, BEVs, compressed natural gas (CNG) vehicles, and fuel cell vehicles (FCVs);
- Accounting for transfer of CO_2 credits between regulated fleets; and
- Accounting for carried-forward (a.k.a. "banked") CO_2 credits, including credits from model years earlier than modeled explicitly.

As further discussed in the NPRM, although EPA had previously developed a vehicle simulation tool ("ALPHA") and a fleet compliance model ("OMEGA"), and had applied these in prior actions, having considered the facts before the Agency in 2018, EPA determined that "it is reasonable and appropriate to use DOE/Argonne's model for full-vehicle simulation, and to use DOT's CAFE model for analysis of regulatory alternatives."[66]

As discussed below and in Section VI, some commenters—some citing deliberative EPA staff communications during NPRM development~~, and one submitting comments by a former EPA staff member closely involved in the origination of the above-mentioned OMEGA model~~—took strong exception to EPA's decision to rely on DOE/Argonne and DOT-originated models as the basis for analysis informing EPA's decisions regarding CO_2 standards. Some commenters argued that the EPA Administrator must consider available ~~exclusively~~ models and analysis originating with EPA staff, and that to instead rely exclusively on models and analysis known to be fundamentally flawed ~~do otherwise~~ would be arbitrary and capricious. As explained below (and as explained in the NPRM), it is reasonable for the Administrator to consider analysis and information produced from many sources, including, in this instance, the DOE/Argonne and DOT models. The Administrator has the discretion to determine what information reasonably and appropriately informs decisions regarding the issuance and revision of emissions standards under section 202(a) of the CAA. Some commenters conflated models with decisions, suggesting that the former mechanically *determine* the latter. The CAA authorizes the EPA Administrator, not a model, to make decisions about emissions standards, just as EPCA provides similar authority to the Secretary. Models produce analysis, the results of which help to inform decisions. However, in making such decisions, the Administrator ~~may and should~~ consider other relevant information beyond the outputs of any models—including public comment—and, in any event, must exercise judgment in establishing appropriate standards.

Commented [A24]: CHANGE AS SHOWN: We believe it is not appropriate to characterize the commenters in such a manner as it appears biased. EPA prefers to factually state the comments, and not to provide partial lists of a commenter's past work experience or attempt to characterize their credentials.

[66] 83 FR 42986, 43000 (Aug. 24, 2018).

Some commenters conflated models with inputs and/or with results of the modeling. All of the models mentioned above rely on inputs, including not only data (i.e., facts), but also estimates (inputs about the future are estimates, not data). Given these inputs, the models produce estimates—ultimately, the agencies' reported estimates of the potential impacts of standards under consideration. In other words, inputs do not define models; models use inputs. Therefore, disagreements about inputs do not logically extend to disagreements about models. Similarly, while models determine resulting outputs, they do so based on inputs. Therefore, disagreements about results do not necessarily imply disagreements about models; they may merely reflect disagreements about inputs. With respect to the Administrator's decisions regarding models underlying today's analysis, comments regarding inputs, therefore, are more appropriately addressed separately, which is done so below in Section VI.

The EPA Administrator's decision to continue relying on the DOE/Argonne Autonomie tool and DOT CAFE model rather than on the corresponding tools developed by EPA staff is informed by consideration of comments on results and on technical aspects of the models themselves. As discussed below, some commenters questioned specific aspects of the CAFE model's simulation of manufacturer's potential responses to CO_2 standards. Considering these comments, the CAFE model applied in the final rule's analysis includes some revisions and updates. For example, the "effective cost" metric used to select among available opportunities to apply fuel-saving technologies now uses a "cost per credit" metric rather than the metric used for the NPRM. Also, the model's representation of sales "multipliers" EPA has included for CNG vehicles, PHEVs, BEVs, and FCVs reflects current EPA regulations or, as an input-selectable option, an alternative approach under consideration. On the other hand, some commenters questioning the CAFE model's approach to some CO_2 program features appear to ignore the fact that prior analysis by EPA (using EPA's OMEGA) model likewise did not account for the same program features. For example, some stakeholders took issue with the CAFE model's approach to accounting for banked CO_2 credits and, in particular, credits banked prior to the model years accounted for explicitly in the analysis. In the course of updating the basis for analysis fleet from model year 2016 to model year 2017, the agencies have since updated corresponding inputs. However, even though the ability to carry forward credits impacts outcomes, EPA's OMEGA model used in previous rulemakings, while designed around the implicit assumption of credit banking within a firm, ~~it~~ does not model explicitly credit banking. ~~never did not attempted to account for credit banking and, indeed, lacking a year-by-year structure, *cannot* account for credit banking~~. Therefore, ~~at least~~ with respect to this important CO_2 program flexibility, the CAFE model provides a ~~superior~~ reasonable basis for estimating actual impacts of ~~new~~ the revised ~~CO_2~~ CO_2 standards.

Commented [A25]: **REVISE:** The Oct-3 2019 CAFE model version reviewed by EPA does not characterize the multipliers according to either current or proposed regulations.

Commented [A26]: **CHANGE AS SHOWN:** This characterization of the OMEGA model is not correct, thus we have modified the sentence. Please see EPA Report EPA-420-R-09-016 for additional information.

For its part, NHTSA remains confident that the combination of the Autonomie and CAFE models remains the best available for CAFE rulemaking analysis, and notes, as discussed below, that even the environmental group coalition stated that the CAFE model is aligned with EPCA requirements.[67] In late 2001, after Congress discontinued an extended series of budget "riders" prohibiting work on CAFE standards, NHTSA and the DOT Volpe Center began development of a modeling system appropriate for CAFE rulemaking analysis, because other available models were not designed with this purpose in mind, and lacked capabilities important for CAFE

[67] Environmental group coalition, NHTSA-2018-0067-12000, Appendix A, at 24-25.

rulemakings. For example, although NEMS had procedures to account for CAFE standards, those procedures did not provide the ability to account for specific manufacturers, as is especially relevant to the statutory requirement that NHTSA consider the economic practicability of any new CAFE standards. Also, as early as the first rulemaking making use of this early CAFE model, commenters stressed the importance of product redesign schedules, leading developers to introduce procedures to account for product cadence. In the 2003 notice regarding light truck standards for MYs 2005-2007, NHTSA stated that "we also changed the methodology to recognize that capital costs require employment of technologies for several years, rather than a single year.... In our view, this makes the Volpe analysis more consistent with the [manually implemented] Stage analysis and better reflects actual conditions in the automotive industry."[68] Since that time, NHTSA and the Volpe Center have significantly refined the CAFE model with each of rulemaking. For example, for the 2006 rulemaking regarding standards for MYs 2008-2011 light trucks, NHTSA introduced the ability to account for attribute-based standards, account for the social cost of CO_2 emissions, estimate stringencies at which net benefits would be maximized, and perform probabilistic uncertainty analysis (i.e., Monte Carlo simulation).[69] For the 2009 rulemaking regarding standards for MY 2011 passenger cars and light trucks, we introduced the ability to account for attribute-based passenger car standards, and the ability to apply "synergy factors" to estimate how some technology pairings impact fuel consumption.[70] For the 2010 rulemaking regarding standards for MYs 2012-2016, we introduced procedures to account for FFV credits, and to account for product planning as a multiyear consideration.[71] For the 2012 rulemaking regarding standards for MYs 2017-2025, we introduced several new procedures, such as (1) accounting for electricity used to charge electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs), (2) accounting for use of ethanol blends in flexible-fuel vehicles (FFVs), (3) accounting for costs (i.e., "stranded capital") related to early replacement of technologies, (4) accounting for previously-applied technology when determining the extent to which a manufacturer could expand use of the technology, (5) applying technology-specific estimates of changes in consumer value, (6) simulating the extent to which manufacturers might utilize EPCA's provisions regarding generation and use of CAFE credits, (7) applying estimates of fuel economy adjustments (and accompanying costs) reflecting increases in air conditioner efficiency, (8) reporting privately-valued benefits, (9) simulating the extent to which manufacturers might voluntarily apply technology beyond levels needed for compliance with CAFE standards, and (10) estimating changes in highway fatalities attributable to any applied reductions in vehicle mass.[72] Also for this 2012 rulemaking, we began making use of Autonomie to estimate fuel consumption impacts of different combinations of technologies, using these estimates to specify inputs to the CAFE model.[73] In 2016, providing analyses for both the draft TAR regarding light-duty CAFE standards and the final rule regarding fuel consumption standards for heavy-duty pickup trucks and vans, we greatly expanded our use of Autonomie-based full vehicle simulations and introduced the ability to simulate compliance with

[68] 68 FR at 16885 (Apr. 7, 2003).
[69] 71 FR at 17566 *et seq.* (Apr. 6, 2006).
[70] 74 FR at 14196 *et seq.* (Mar. 30, 3009).
[71] 75 FR at 25599 *et seq.* (May 7, 2010).
[72] 77 FR 63009 *et seq.* (Oct. 15, 2012).
[73] 77 FR at 62712 *et seq.* (Oct. 15, 2012).

attribute-based standards for heavy-duty pickups and vans.[74] And, as discussed in at length in the NPRM and below, for this rulemaking, we have, among other things, refined procedures to account for impacts on highway travel and safety, added procedures to simulate compliance with CO_2 standards, refined procedures to account for compliance credits, and added procedures to account for impacts on sales, scrappage, and employment. We have also significantly revised the model's graphical user interface (GUI) in order to make the model easier to operate and understand. Like any model, both Autonomie and the CAFE model benefit from ongoing refinement. However, NHTSA is confident that this combination of models produces a more realistic characterization of the potential impacts of new CAFE standards than would an other combination of available models. Some stakeholders, while commenting on specific aspects of the inputs, models, and/or results, commended the agencies' exclusive reliance on the DOE/Argonne Autonomie tool and DOT CAFE model. With respect to CO_2 standards, these stakeholders noted not only technical reasons to use these models rather than the EPA models, but also other reasons such as efficiency, transparency, and ease with which outside parties can exercise models and replicate the agencies' analysis. These comments are discussed below and in Section VI.

Nevertheless, some comments regarding the model's handling of CAFE and/or CO_2 standards, and some comments regarding the model's estimation of resultant impacts, led the agencies to make changes to specific aspects of the model. Comments on and changes to the inputs and model are discussed below and in Section VI; results are discussed in Section VII and in the accompanying RIA; and the meaning of results in the context of the applicable statutory requirements is discussed in Section VIII.

As explained, the analysis is designed to reflect a number of statutory and regulatory requirements applicable to CAFE and tailpipe CO_2 standard setting. EPCA contains a number of requirements governing the scope and nature of CAFE standard setting. Among these, some have been in place since EPCA was first signed into law in 1975, and some were added in 2007, when Congress passed EISA and amended EPCA. The CAA, as discussed elsewhere, provides EPA with very broad authority under Section 202(a), and does not contain EPCA/EISA's prescriptions. In the interest of harmonization, however, EPA has adopted some of the EPCA/EISA requirements for the CAFE program into its tailpipe CO_2 regulations, and NHTSA, in turn, has created some additional flexibilities by regulation not expressly envisioned by EPCA/EISA in order to harmonize better with some of EPA's programmatic decisions. EPCA/EISA requirements regarding the technical characteristics of CAFE standards and the analysis thereof include, but are not limited to, the following, and the analysis reflects these requirements as summarized:

Corporate Average Standards: 49 U.S.C. 32902 requires standards that apply to the average fuel economy levels achieved by each corporation's fleets of vehicles produced for sale

[74] 81 FR at 73743 *et seq.* (Oct. 25, 2016); Draft TAR, available at Docket No. NHTSA-2016-0068-0001, Chapter 13.

in the U.S.[75] CAA Section 202(a) ~~does not preclude~~gives the EPA Administrator discretion to establish the form of the ~~from expressing~~ CO_2 standards ~~as *de facto* fleet average requirements.~~ and in the 2010 Rule first establishing EPA light-duty vehicle CO2 standards EPA adopted a fleet-wide average approach. ~~EPA has adopted a similar approach in the interest of harmonization.~~ The CAFE Model, used by the agencies to conduct the bulk of today's analysis, calculates the CAFE and CO_2 levels of each manufacturer's fleets based on estimated *production* volumes and characteristics, including fuel economy levels. of distinct vehicle models that could be produced for sale in the U.S.

Separate Standards for Passenger Cars and Light Trucks: 49 U.S.C. 32902 requires the Secretary of Transportation to set CAFE standards separately for passenger cars and light trucks. CAA Section 202(a) ~~does not preclude~~allows the EPA Administrator ~~from~~ to specify~~ing~~ CO_2 standards separately for passenger cars and light trucks, and EPA has adopted such an ~~similar~~ approach ~~in the interest of harmonization~~. The CAFE Model accounts separately for passenger cars and light trucks, including *differentiated* standards and compliance.

Attribute-Based Standards: 49 U.S.C. 32902 requires the Secretary of Transportation to define CAFE standards as mathematical functions expressed in terms of one or more vehicle attributes related to fuel economy. This means that for a given manufacturer's fleet of vehicles produced for sale in the U.S. in a given regulatory class and model year, the applicable minimum CAFE requirement (i.e., the numerical value of the requirement) is computed based on the applicable mathematical function, and the mix and attributes of vehicles in the manufacturer's fleet. In the 2010 Rule first establishing CO2 standards, EPA also adopted an attribute-based standard under its broad CAA Section 202(a) authority. ~~similarly does not preclude the EPA Administrator from defining CO_2 standards, and EPA has adopted a similar approach in the interest of harmonization.~~ The CAFE Model accounts for such functions and vehicle attributes explicitly.

Separately Defined Standards for Each Model Year: 49 U.S.C. 32902 requires the Secretary to set CAFE standards (separately for passenger cars and light trucks) at the maximum feasible levels in each model year. CAA Section 202(a) allows EPA to establish standards for each model year of vehicles, and EPA has chosen to do so for this final rule, similar to the approach taken in the previous light-duty vehicle CO2 standard setting rules.~~does not preclude the EPA Administrator from setting CO_2 standards separately for each model years, and EPA has adopted a similar approach in the interest of harmonization.~~ The CAFE Model represents each model year explicitly, and accounts for the production relationships between model years.[76]

Commented [A27]: **CHANGE AS SHOWN:** Correcting references to CAA authority, and harmonization with CAFE was just one of the reasons EPA adopted a fleet-wide average approach in the 2010 final rule.

Commented [A28]: **CHANGE AS SHOWN:** Harmonization with CAFE was just one of the reasons EPA adopted a fleet-wide average approach in the 2010 final rule.

Edits in the following paragraphs correct references to EPA's CAA authority.

[75] This differs from safety standards ~~and traditional emissions standard~~, which apply separately to each vehicle. For example, every vehicle produced for sale in the U.S. must, on its own, meet all applicable federal motor vehicle safety standards (FMVSS), but no vehicle produced for sale must, on its own, federal fuel economy standards. Rather, each manufacturer is required to produce a mix of vehicles that, taken together, achieve an average fuel economy level no less than the applicable minimum level.

[76] For example, a new engine first applied to given vehicle model/configuration in model year 2020 will most likely be "carried forward" to model year 2021 of that same vehicle model/configuration, in order to reflect the fact that manufacturers do not apply brand-new engines to a given vehicle model every single year.

Separate Compliance for Domestic and Imported Passenger Car Fleets: 49 U.S.C. 32904 requires the EPA Administrator to determine CAFE compliance separately for each manufacturers' fleets of domestic passenger cars and imported passenger cars, which manufacturers must consider as they decide how to improve the fuel economy of their passenger car fleets. CAA 202(a) does not preclude the EPA Administrator from determining compliance with CO_2 standards separately for a manufacturer's domestic and imported car fleets assuming the Administrator has a resonable basis for doing so. However, the GHG program EPA designed in the 2010 and 2012 Final Rules did not include such a distinction, and EPA did not propose or ask for comment on taking such an approach for the SAFE rule.~~, but EPA has declined to adopt a similar approach.~~ The CAFE Model is able to account explicitly for this requirement when simulating manufacturers' potential responses to CAFE standards, but combines any given manufacturer's domestic and imported cars into a single fleet when simulating that manufacturer's potential response to CO_2 standards.

Minimum CAFE Standards for Domestic Passenger Car Fleets: 49 U.S.C. 32902 requires that domestic passenger car fleets achieve CAFE levels no less than 92 percent of the industry-wide average level required under the applicable attribute-based CAFE standard, as projected by the Secretary at the time the standard is promulgated. CAA 202(a) does not preclude the EPA Administrator from correspondingly requiring that domestic passenger car fleets achieve CO_2 levels no greater than 108.7 percent (1/0.92 = 1.087) of the projected industry-wide average CO_2 requirement under the attributed-based standard, assuming the Administrator has a reasonable basis for doing so. However, the GHG program EPA designed in the 2010 and 2012 Final Rules did not include such a distinction, and EPA did not propose or ask for comment on taking such an approach for the SAFE rule~~, but EPA has declined to adopt a similar approach~~. The CAFE Model is able to account explicitly for this requirement for CAFE standards, and sets this requirement aside for CO_2 standards.

Civil Penalties for Noncompliance: 49 U.S.C. 32912 prescribes a rate (in dollars per tenth of a mpg) at which the Secretary is to levy civil penalties if a manufacturer fails to comply with a CAFE standard for a given fleet in a given model year, after considering available credits. Some manufacturers have historically demonstrated a willingness to treat CAFE noncompliance as an "economic" choice, electing to pay civil penalties rather than achieving full numerical compliance across all fleets. The CAFE Model calculates civil penalties for CAFE shortfalls and provides means to estimate that a manufacturer might stop adding fuel-saving technologies once continuing to do so would be effectively more "expensive" (after accounting for fuel prices and buyers' willingness to pay for fuel economy) than paying civil penalties. In contrast, the CAA does not authorize the EPA Administrator to allow manufacturers to sell noncompliant light-duty vehicles ~~fleets~~ and instead only pay civil penalties~~; manufacturers who choose to pay civil penalties for CAFE compliance tend to employ EPA's more-extensive programmatic flexibilities to meet tailpipe CO_2 emissions standards~~. Thus, the CAFE Model does not allow civil penalty payment as an option for CO_2 standards.

Commented [A29]: CHANGE AS SHOWN: This is not necessarily true, it is not clear what "more extensive programmatic flexibilities," means, and in any case does not seem relevant to describing how civil penalties are modeled, so EPA suggests deleting.

Dual-Fueled and Dedicated Alternative Fuel Vehicles: For purposes of calculating CAFE levels used to determine compliance, 49 U.S.C. 32905 and 32906 specify methods for calculating the fuel economy levels of vehicles operating on alternative fuels to gasoline or diesel through MY 2020. After MY 2020, methods for calculating alternative fuel vehicle (AFV) fuel

economy are governed by regulation. The CAFE Model is able to account for these requirements explicitly for each vehicle model. However, 49 U.S.C. 32902 requires that maximum feasible CAFE standards be set in a manner that does not presume manufacturers can respond by producing new dedicated alternative fuel vehicle (AFV) models. The CAFE model can be run in a manner that excludes the additional application of dedicated AFV technologies in model years for which maximum feasible standards are under consideration. As allowed under NEPA for analysis appearing in EISs informing decisions regarding CAFE standards, the CAFE Model can also be run without this analytical constraint. CAA 202(a) does not preclude the EPA Administrator adopting analogous provisions, but EPA has instead ~~opted~~ established through regulation to ~~"count"~~include dual- and alternative fuel vehicles on a CO_2 basis ~~(and through MY 2026, to set aside emissions from electricity generation)~~in a manufacturer's fleetwide average for purposes of determining compliance with CO2 standards. The CAFE model accounts for this treatment of dual- and alternative fuel vehicles when simulating manufacturers' potential responses to CO_2 standards. For natural gas vehicles, both dedicated and dual-fueled, EPA is establishing a multiplier of 2.0 for model years 2022-2026. ~~EPA has also elected to support its decisions with analysis that considers the potential that manufacturers would respond to new standards by producing new AFV models, and the CAFE model is able to reflect this approach.~~

Commented [A30]: CHANGE AS SHOWN: It is not clear what this means, and to EPA's knowledge the analysis for SAFE rule does not attempt to project manufacturer's production of e.g., FFVs or NGVs, so we don't see the purpose of this sentence.

Other edits in this paragraph correct references to EPA's GHG program.

Creation and Use of Compliance Credits: 49 U.S.C. 32903 provides that manufacturers may earn CAFE "credits" by achieving a CAFE level beyond that required of a given fleet in a given model year, and specifies how these credits may be used to offset the amount by which a different fleet falls short of its corresponding requirement. These provisions allow credits to be "carried forward" and "carried back" between model years, transferred between regulated classes (domestic passenger cars, imported passenger cars, and light trucks), and traded between manufacturers. However, these provisions also impose some specific statutory limits. For example, CAFE compliance credits can be carried forward a maximum of five model years and carried back a maximum of three model years. Also, EPCA/EISA caps the amount of credit that can be transferred between passenger car and light truck fleets, and probibits manufacturers from applying traded or transferred credits to offset a failure to achieve the applicable minimum standard for domestic passenger cars. The CAFE Model explicitly simulates manufacturers' potential use of credits carried forward from prior model years or transferred from other fleets.[77]

[77] As explained in Section VI, the CAFE Model does not explicitly simulate the potential that manufacturers would carry CAFE or CO_2 credits back (i.e., borrow) from future model years, or acquire and use CAFE compliance credits from other manufacturers. At the same time, because EPA has ~~elected to~~ not limited credit trading, the CAFE Model can be exercised in a manner that simulates unlimited (a.k.a. "perfect") CO_2 compliance credit trading throughout the industry (or, potentially, within discrete trading "blocs"). The agencies believe there is significant uncertainty in how manufacturers may choose to employ these particular flexibilities in the future: for example, while it is reasonably foreseeable that a manufacturer who over-complies in one year may "coast" through several subsequent years relying on those credits rather than continuing to make technology improvements, it is harder to assume with confidence that manufacturers will rely on future technology investments (that may not pan out as expected, as if market demand for "target-beater" vehicles is lower than expected) to offset prior-year shortfalls, or whether/how manufacturers will trade credits with market competitors rather than making their own technology investments. Historically, carry-back and trading have been much less utilized than carry-forward, for a variety of reasons including higher risk and preference not to "pay competitors to make fuel economy improvements we should be making" (to paraphrase one manufacturer), although the agencies recognize that carry-back and trading are used more frequently when standards require more technology application than manufacturers believe their

49 U.S.C. 32902 prohibits consideration of manufacturers' potential application of CAFE compliance credits when setting maximum feasible CAFE standards. The CAFE Model can be operated in a manner that excludes the application of CAFE credits after a given model year. CAA 202(a) does not preclude the EPA Administrator adopting analogous provisions. In its light-duty vehicle ~~CO2~~GHG program, EPA has ~~opted to~~ limited the ~~"life"~~duration of compliance credits from most model years to 5 years, and to limit ~~borrowing~~ credit deficit carryforward to 3 years, ~~but~~ and has not adopted any limits on transfers (between fleets) or trades (between manufacturers) of compliance credits. The CAFE Model is able to account for the absence of limits on transfers of CO_2 standards. Insofar as the CAFE model can be exercised in a manner that simulates trading of CO_2 compliance credits, such simulations treat trading as unlimited.[78] EPA has considered manufacturers' ability to use credits as part of its decisions on the~~se~~ final CO2 standards, and the CAFE model is now able to account for that.

Commented [A31]: CHANGE AS SHOWN: Correcting references to the EPA GHG program, in this and next paragraphs.

Statutory Basis for Stringency: 49 U.S.C. 32902 requires the Secretary to set CAFE standards at the maximum feasible levels, considering technological feasibility, economic practicability, the need of the Nation to conserve energy, and the impact of other government standards. EPCA/EISA authorizes the Secretary to interpret these factors, and as the Department's interpretation has evolved, NHTSA has continued to expand and refine its qualitative and quantitative analysis. For example, as discussed below in Section VI, the Autonomie simulations reflect the agencies' judgment that it would not be economically practicable for a manufacturer to "split" an engine shared among many vehicle model/configurations into a myriad of versions each optimized to a single vehicle model/configuration. Also responding to evolving interpretation of these EPCA/EISA factors, the CAFE Model has been expanded to address additional impacts in an integrated manner. For example, the CAFE Model version used for the NPRM analysis included the ability to estimate impacts on labor utilization internally, rather than as an external "off model" or "post processing" analysis. In addition, NEPA requires the Secretary to issue an EIS that documents the estimated impacts of regulatory alternatives under consideration. The EIS accompanying today's notice documents changes in emission inventories as estimated using the CAFE model, but also documents corresponding estimates—based on the application of other models documented in the EIS, of impacts on the global climate, on tropospheric air quality, and on human health. Regarding CO_2 standards, CAA 202(a) provides ~~general~~ broad authority for the establishment of motor vehicle emissions standards, and the final rule's analysis, like that accompanying the agencies' proposal, addresses ~~impacts~~ factors relevant to the EPA Administrator's decision making, such as ~~impacts on the application of~~ technologically

markets will bear. Given the uncertainty just discussed, and given also the fact that the agencies have yet to resolve some of analytical challenges associated with simulating use of these flexibilities, the agencies consider borrowing and trading to involve sufficient risk that it is prudent to support today's decisions with analysis that sets aside the potential that manufacturers could come to depend widely on borrowing and trading. While compliance costs in real life may be somewhat different from what is modeled today as a result of this analytical decision, that is broadly true no matter what, and the agencies do not believe that the difference would be so great that it would change the policy outcome.

[78] To avoid making judgments (that would invariably turn out to be at least somewhat incorrect) about possible future trading activity, the model simulates trading by combining all manufacturers into a single entity, so that the most cost-effective choices are made for the fleet as a whole.

feasibility, air quality impacts, costs to industry and consumers, and lead time necessary for compliance~~, and benefits and costs to society~~.

Other Factors: Beyond these statutory requirements applicable to DOT and/or EPA are a number of specific technical characteristics of CAFE and/or CO_2 regulations that are also relevant to the construction of today's analysis. These are discussed at greater length in Section VI. ~~For example, EPA has defined procedures for calculating average CO_2 levels, and has revised procedures for calculating CAFE levels, to reflect manufacturers' application of "off-cycle" technologies that increase fuel economy (and reduce CO_2 emissions) in ways not reflected by the long-standing test procedures used to measure fuel economy.~~ Although too little information is available to account for ~~these~~ off-cycle credit provisions explicitly in the same way that the agencies have accounted for other technologies, the CAFE Model does include and makes use of inputs reflecting the agencies' expectations regarding the extent to which manufacturers may earn such credits, along with estimates of corresponding costs. Similarly, the CAFE Model includes and makes use of inputs regarding credits that the existing EPA program ~~has elected to~~ allows manufacturers to earn toward CO_2 levels (not CAFE) based on the use of air conditioner refrigerants with lower global warming potential (GWP), or on the application of technologies to reduce refrigerant leakage. In addition, the existing EPA program ~~has elected to~~ provides that through model year 2021, manufacturers may apply "multipliers" to plug-in hybrid electric vehicles, dedicated electric vehicles, fuel cell vehicles, and ~~hydrogen~~ natural gas vehicles (and in this final rule EPA is providing that manufacturers of natural gas vehicles may apply a 2X multiplier from MY 2022-2026), such that when calculating a fleet's average CO_2 levels (not CAFE), in the applicable model years, the manufacturer may, for example, "count" each electric vehicle twice. The CAFE Model accounts for these multipliers~~, based on either current regulatory provisions or on alternative approaches~~. Although these are examples of regulatory provisions that arise from the exercise of discretion rather than specific statutory mandate, they can materially impact outcomes. Section VI explains in greater detail how today's analysis addresses them.

Commented [A32]: CHANGE AS SHOWN: In EPA's write-up for the justification for the final rule standards, similar to the SAFE NPRM, net benefits do not play a role in the Administrator's determination, so we recomment deleting this part of this sentence.

Commented [A33]: CHANGE AS SHOWN: Text like this implies that EPA is newly establishing these provisions in this final rule, when these are aspects of the current program. Other edits in this paragraph are for clarity and correcting references to EPA's GHG program.

Other edits in this paragraph correct references to EPA's GHG program.

B. Benefits of analytical approach

The agencies' analysis of CAFE and CO_2 standards involves two basic elements: first, estimating ways each manufacturer could potentially respond to a given set of standards in a manner that considers potential consumer response; and second, estimating various impacts of those responses. Estimating manufacturers' potential responses involves simulating manufacturers' decision-making processes regarding the year-by-year application of fuel-saving technologies to specific vehicles. Estimating impacts involves calculating resultant changes in new vehicle costs, estimating a variety of costs (e.g., for fuel) and effects (e.g., CO_2 emissions from fuel combustion) occurring as vehicles are driven over their lifetimes before eventually being scrapped, and estimating the monetary value of these effects. Estimating impacts also involves consideration of the response of consumers—e.g., whether consumers will purchase the vehicles and in what quantities. Both of these basic analytical elements involve the application of many analytical inputs.

As mentioned above, the agencies' analysis uses the CAFE model to estimate manufacturers' potential responses to new CAFE and CO_2 standards and to estimate various

impacts of those responses. DOT's Volpe National Transportation Systems Center (often simply referred to as the "Volpe Center") develops, maintains, and applies the model for NHTSA. NHTSA has used the CAFE model to perform analyses supporting every CAFE rulemaking since 2001, and the 2016 rulemaking regarding heavy-duty pickup and van fuel consumption and CO_2 emissions also used the CAFE model for analysis.[79]

NHTSA recently arranged for a formal peer review of the model. In general, reviewers' comments strongly supported the model's conceptual basis and implementation, and commenters provided several specific recommendations. The agency agreed with many of these recommendations and has worked to implement them wherever practicable. Implementing some of the recommendations would require considerable further research, development, and testing, and will be considered going forward. For a handful of other recommendations, the agency disagreed, often finding the recommendations involved considerations (e.g., other policies, such as those involving fuel taxation) beyond the model itself or were based on concerns with inputs rather than how the model itself functioned. A report available in the docket for this rulemaking presents peer reviewers' detailed comments and recommendations, and provides DOT's detailed responses.[80]

As also mentioned above, the agencies use EPA's MOVES model to estimate tailpipe emission factors, and use DOE/EIA's NEMS to estimate fuel prices,[81] use Argonne's GREET model to estimate downstream emissions rates.[82] DOT also sponsored DOE/Argonne to use the Autonomie full-vehicle modeling and simulation tool to estimate the fuel economy impacts for roughly a million combinations of technologies and vehicle types.[83],[84]

EPA developed two models after 2009, referred to as the "ALPHA" and "OMEGA" models, which provide some of the same capabilities as the Autonomie and CAFE models. EPA applied the OMEGA model to conduct analysis of tailpipe CO_2 emissions standards promulgated in 2010 and 2012, and the ALPHA and OMEGA models to conduct analysis discussed in the

[79] While both agencies used the CAFE Model to simulate manufacturers' potential responses to standards, some model inputs differed EPA's and DOT's analyses, and EPA also used the EPA MOVES model to calculate resultant changes in emissions inventories. *See* 81 FR 73478, 73743 (Oct. 25, 2016).

[80] Docket No. NHTSA-2018-0067-0055.

[81] *See* https://www.eia.gov/outlooks/aeo/info_nems_archive.php. Today's notice uses fuel prices estimated using the Annual Energy Outlook (AEO) 2019 version of NEMS (see https://www.eia.gov/outlooks/archive/aeo19/ and https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2019&cases=ref2019&sourcekey=0).

[82] Information regarding GREET is available at https://greet.es.anl.gov/index.php. Availability of NEMS is discussed at https://www.eia.gov/outlooks/aeo/info_nems_archive.php. Today's notice uses fuel prices estimated using the AEO 2019 version of NEMS.

[83] As part of the Argonne simulation effort, individual technology combinations simulated in Autonomie were paired with Argonne's BatPAC model to estimate the battery cost associated with each technology combination based on characteristics of the simulated vehicle and its level of electrification. Information regarding Argonne's BatPAC model is available at http://www.cse.anl.gov/batpac/.

[84] Furthermore, the impact of engine technologies on fuel consumption, torque, and other metrics was characterized using GT POWER simulation modeling in combination with other engine modeling that was conducted by IAV Automotive Engineering, Inc. (IAV). The engine characterization "maps" resulting from this analysis were used as inputs for the Autonomie full-vehicle simulation modeling. Information regarding GT Power is available at https://www.gtisoft.com/gt-suite-applications/propulsion-systems/gt-power-engine-simulation-software.

above-mentioned 2016 Draft TAR and Proposed and 2017 Initial Final Determinations regarding standards beyond 2021. In an August 2017 notice, the agencies requested comments on, among other things, whether EPA should use alternative methodologies and modeling, including DOE/Argonne's Autonomie full-vehicle modeling and simulation tool and DOT's CAFE model.[85]

Having reviewed comments on the subject and having considered the matter fully, the agencies have determined it is reasonable and appropriate to use DOE/Argonne's model for full-vehicle simulation, and to use DOT's CAFE model for analysis of regulatory alternatives. EPA interprets Section 202(a) of the CAA as giving the agency broad discretion in how it develops and sets CO_2 emissions standards for light-duty vehicles. Nothing in Section 202(a) mandates that EPA use any specific model or set of models for analysis of potential CO_2 standards for light-duty vehicles. EPA weighs many factors when determining appropriate levels for CO_2 standards, including the cost of compliance (*see* Section 202(a)(2)), lead time necessary for compliance (*id.*), safety (*see NRDC v. EPA*, 655 F.2d 318, 336 n. 31 (D.C. Cir. 1981)) and other impacts on consumers,[86] and energy impacts associated with use of the technology.[87] Using the CAFE model allows consideration of a number of factors. The CAFE model explicitly evaluates the cost of compliance for each manufacturer, each fleet, and each model year; it accounts for lead time necessary for compliance by directly incorporating estimated manufacturer production cycles for every vehicle in the fleet, ensuring that the analysis does not assume vehicles can be redesigned to incorporate more technology without regard to lead time considerations; it provides information on safety effects associated with different levels of standards and information about many other impacts on consumers, and it calculates energy impacts (i.e., fuel saved or consumed) as a primary function, besides being capable of providing information about many other factors within EPA's broad CAA discretion to consider.

Because the CAFE model simulates a wide range of actual constraints and practices related to automotive engineering, planning, and production, such as common vehicle platforms, sharing of engines among different vehicle models, and timing of major vehicle redesigns, the analysis produced by the CAFE model provides a transparent and realistic basis to show pathways manufacturers could follow over time in applying new technologies, which helps better assess impacts of potential future standards. Furthermore, because the CAFE model also accounts fully for regulatory compliance provisions (now including CO_2 compliance provisions), such as adjustments for reduced refrigerant leakage, production "multipliers" for some specific types of vehicles (e.g., PHEVs), and carried-forward (i.e., banked) credits, the CAFE model provides a transparent and realistic basis to estimate how such technologies might be applied over time in response to CAFE or CO_2 standards.

There are sound reasons for the agencies to use the CAFE model ~~going forward~~ in this final rulemaking. First, the CAFE and CO_2 fact analyses are inextricably linked. Furthermore, the analysis produced by the CAFE model and DOE/Argonne's Autonomie addresses the

Commented [A34]: CHANGE AS SHOWN: Clarifying that this decision is limited to this final rule, not future actions ("going forward").

[85] 82 FR 39551, 39553 (Aug. 21, 2017).

[86] Since its earliest Title II regulations, EPA has considered the safety of pollution control technologies. *See* 45 FR 14496, 14503 (1980).

[87] *See George E. Warren Corp. v. EPA*, 159 F.3d 616, 623-624 (D.C. Cir. 1998) (ordinarily permissible for EPA to consider factors not specifically enumerated in the Act).

agencies' analytical needs. The CAFE model provides an explicit year-by-year simulation of manufacturers' application of technology to their products in response to a year-by-year progression of CAFE standards and accounts for sharing of technologies and the implications for timing, scope, and limits on the potential to optimize powertrains for fuel economy. In the real world, standards ~~actually~~ are specified on a year-by-year basis. ~~not simply some single year well into the future~~, and manufacturers' year-by-year plans involve some vehicles "carrying forward" technology from prior model years and some other vehicles possibly applying "extra" technology *in anticipation of standards in ensuing model years*, and manufacturers' planning also involves applying credits carried forward between model years. ~~Furthermore, manufacturers cannot optimize the powertrain for fuel economy on every vehicle model configuration—for example, a given engine shared among multiple vehicle models cannot practicably be split into different versions for each configuration of each model, each with a slightly different displacement.~~ The CAFE model is designed to account for these real-world factors.

Commented [A35]: CHANGE AS SHOWN: This text explains decisions about inputs to the model, not the model itself. EPA suggests deleting as this conflates inputs and model, in the same way that the draft preamble text on page 24 cautioned against.

Considering the technological heterogeneity of manufacturers' current product offerings, and the wide range of ways in which the many fuel economy-improving/CO_2 emissions-reducing technologies included in the analysis can be combined, the CAFE model has been designed to use inputs that provide an estimate of the fuel economy achieved for many tens of thousands of different potential combinations of fuel-saving technologies. Across the range of technology classes encompassed by the analysis fleet, today's analysis involves more than a million such estimates. While the CAFE model requires no specific approach to developing these inputs, the National Academy of Sciences (NAS) has recommended, and stakeholders have commented, that full-vehicle simulation provides the best balance between realism and practicality. DOE/Argonne has spent several years developing, applying, and expanding means to use distributed computing to exercise its Autonomie full-vehicle modeling and simulation tool over the scale necessary for realistic analysis of CAFE or average tailpipe CO_2 emissions standards. This scalability and related flexibility (in terms of expanding the set of technologies to be simulated) makes Autonomie well-suited for developing inputs to the CAFE model.

In addition, DOE/Argonne's Autonomie also has a long history of development and widespread application by a ~~much~~ wider range of users in government, academia, and industry. Many of these users apply Autonomie to inform funding and design decisions. These real-world exercises have contributed significantly to aspects of Autonomie important to producing realistic estimates of fuel economy levels and CO_2 emission rates, such as estimation and consideration of performance, utility, and driveability metrics (e.g., towing capability, shift business, frequency of engine on/off transitions). This steadily increasing realism has, in turn, steadily increased confidence in the appropriateness of using Autonomie to make significant investment decisions. Notably, DOE uses Autonomie for analysis supporting budget priorities and plans for programs managed by its Vehicle Technologies Office (VTO). Considering the advantages of DOE/Argonne's Autonomie model, it is reasonable and appropriate to use Autonomie to estimate fuel economy levels and CO_2 emission rates for different combinations of technologies as applied to different types of vehicles.

Commenters have also suggested that the CAFE model's graphical user interface (GUI) facilitates others' ability to use the model quickly—and without specialized knowledge or

training and to comment accordingly.[88] For the NPRM, NHTSA significantly expanded and refined this GUI, providing the ability to observe the model's real-time progress much more closely as it simulates year-by-year compliance with either CAFE or CO_2 standards.[89] Although the model's ability to produce realistic results is independent of the model's GUI, the CAFE model's GUI appears to have facilitated stakeholders' meaningful review and comment during the comment period.

The question of whether EPA~~'s actions~~ should consider and ~~be informed by~~rely on analysis using non-EPA-staff-developed modeling tools has generated considerable debate ~~over time during the 2017-2018 reconsideration of the midterm evaluation and the course of this rulemaking~~. Even prior to the NPRM, certain commenters during the EPA's reconsideration of its 2017 Final Determination had argued that EPA could not consider, in setting tailpipe CO_2 emissions standards, any information derived from non-EPA-staff-developed modeling. Many of the pre-NPRM concerns focused on inputs used by the CAFE model for prior rulemaking analyses.[90, 91, 92] Because inputs are exogenous to any model, they do not determine whether it would be reasonable and appropriate for EPA to use NHTSA's model for analysis. Other concerns focused on certain characteristics of the CAFE model that were developed to align the model better with EPCA and EISA. The model has been revised for this rulemaking to accommodate both EPCA/EISA and CAA analysis, as explained further below. Some commenters also argued that use of any models other than ALPHA and OMEGA for CAA

[88] From Docket Number EPA-HQ-OAR-2015-0827, *see* Comment by Global Automakers, Docket ID EPA-HQ-OAR-2015-0827-9728, at 34.

[89] The updated GUI provides a range of graphs updated in real time as the model operates. These graphs can be used to monitor fuel economy or CO_2 ratings of vehicles in manufacturers' fleets and to monitor year-by-year CAFE (or average CO_2 ratings), costs, avoided fuel outlays, and avoided CO_2-related damages for specific manufacturers and/or specific fleets (e.g., domestic passenger car, light truck). Because these graphs update as the model progresses, they should greatly increase users' understanding of the model's approach to considerations such as multiyear planning, payment of civil penalties, and credit use.

[90] For example, EDF previously stated that "the data that NHTSA needs to input into its model is sensitive confidential business information that is not transparent and cannot be independently verified,…" and it claimed "the OMEGA model's focus on direct technological inputs and costs as opposed to industry self-reported data—ensures the model more accurately characterizes the true feasibility and cost effectiveness of deploying [carbon dioxide] reducing technologies." EDF, EPA-HQ-OAR-2015-0827-9203, at 12. These statements are not correct, as nothing about either the CAFE or OMEGA model either obviates or necessitates the use of CBI to develop inputs.

[91] As another example, CARB previously stated that "another promising technology entering the market was not even included in the NHTSA compliance modeling" and that EPA assumes a five-year redesign cycle, whereas NHTSA assumes a six to seven-year cycle." CARB, EPA-HQ-OAR-2015-0827-9197, at 28. Though presented as criticisms of the models, these comments—at least with respect to the CAFE model actually concern model inputs. NHTSA did not agree with CARB about the commercialization potential of the engine technology in question ("Atkinson 2") and applied model inputs accordingly. Also, rather than applying a one-size-fits-all assumption regarding redesign cadence, NHTSA developed estimates specific to each vehicle model and applied these as model inputs.

[92] As another example, NRDC has argued that EPA should not use the CAFE model because it "allows manufacturers to pay civil penalties in lieu of meeting the standards, an alternative compliance pathway currently allowed under EISA and EPCA." NRDC, EPA-HQ-OAR-2015-0827-9826, at 37. While the CAFE model can simulate civil penalty payment, NRDC's comment appears to overlook the fact that this result depends on model inputs; the inputs can easily be specified such that the CAFE model will set aside civil penalty payment as an alternative to compliance.

analysis would constitute an arbitrary and capricious delegation of EPA's decision-making authority to NHTSA, if NHTSA models are used for analysis instead.[93] As discussed above, the CAFE Model—as with any model—is a tool used to provide analysis, and does not result in regulatory decisions. Decisions about the appropriate level of emission standards and other aspects of the rulemaking are made by EPA ~~in a manner that is informed by~~under its statutory authority and based on relevant information including modeling outputs, sensitivity cases, public comments, any many other pieces of information.

Comments responding to the NPRM's use of the CAFE model and Autonomie rather than also (for CO_2 standards) ALPHA and OMEGA were mixed. For example, the environmental group coalition stated that the CAFE model is aligned with EPCA requirements,[94] but also argued ~~for 13 single-spaced pages~~ (1) that EPA is legally prohibited from "delegat[ing] technical decision-making to NHTSA";[95] (2) that "EPA must exercise its technical and scientific expertise" to develop CO_2 standards and "Anything less is an unlawful abdication of EPA's statutory responsibilities";[96] (3) that EPA staff is much more qualified than DOT staff to conduct analysis relating to standards and has done a great deal of work to inform development of standards;[97] (4) that "The Draft TAR and 2017 Final Determination relied extensively on use of sophisticated EPA analytic tools and methodologies," *i.e.*, the "peer reviewed simulation model ALPHA," "the agency's vehicle teardown studies," and the "peer-reviewed OMEGA model to make reasonable estimates of how manufacturers could add technologies to vehicles in order to meet a fleet-wide [CO_2 emissions] standard";[98] (5) that NHTSA had said in the MYs 2012-2016 rulemaking that the Volpe [CAFE] model was developed to support CAFE rulemaking and incorporates features "that are not appropriate for use by EPA in setting [tailpipe CO_2] standards";[99] (6) allegations that some EPA staff had disagreed with aspects of the NPRM analysis and had requested that "EPA's name and logo should be removed from the DOT-NHTSA Preliminary Regulatory Impact Analysis document" and stated that "EPA is relying upon the technical analysis performed by DOT-NHTSA for the [NPRM]";[100] (7) that EPA had developed "a range of relevant new analysis" that the proposal "failed to consider," including "over a dozen 2017 and 2018 EPA peer reviewed SAE articles";[101] (8) that EPA's OMEGA modeling undertaken during NPRM development "found costs *half* that of NHTSA's findings." "Yet NHTSA did not correct the errors in its modeling and analysis, and the published proposal drastically overestimates the cost of complying….";[102] (9) that some EPA staff had requested that the technology "HCR2" be included in the NPRM analysis. "Yet NHTSA overruled EPA and omitted the technology";[103] (10) that certain EPA staff had initially "rejected use of the

Commented [A36]: DELETE: The reference to "13 single-spaced pages" seems derogatory to the commenter and is unnecessary.

[93] *See, e.g.*, CBD *et al.*, NHTSA-2018-0067-12057, at 9.
[94] Environmental group coalition, NHTSA-2018-0067-12000, Appendix A, at 24-25.
[95] *Id.* at 12.
[96] *Id.* at 14.
[97] *Id.* at 15-17.
[98] *Id.* at 17.
[99] *Id.* at 18.
[100] *Id.* at 19.
[101] *Id.* at 20.
[102] *Id.* at 21.
[103] *Id.* at 21-22.

CAFE model for development of the proposed [tailpipe CO_2] standards";[104] (11) that there are "many specific weaknesses of the modeling results derived in this proposal through use of the Volpe and Autonomie models" and that the CAFE model is "not designed in accordance with" Section 202(a) of the CAA because (A) EPA "is not required to demonstrate that standards are set at the maximum feasible level year-by-year," (B) because EPCA "preclude[s NHTSA] from considering vehicles powered by fuels other than gas or diesel" and EPA is not similarly bound, and (C) because the CAFE model assumed that the value of an overcompliance credit equaled $5.50, the value of a CAFE penalty.[105] Because of all of these things, the environmental group coalition stated that the proposal was "unlawful" and that "Before proceeding with this rulemaking, EPA must consider all relevant materials including these excluded insights, perform its own analysis, and issue a reproposal to allow for public comment."[106]

Some environmental organizations and States contracted for external technical analyses augmenting general comments such as those summarized above. EDF engaged a consultant, Richard Rykowski, for a detailed review of the agencies' analysis.[107] ~~Mr. Rykowski is a former EPA employee who, during 2008-2010, was involved in developing the technical conception and initial design of EPA's OMEGA model as an alternative to DOT's CAFE model, as well as the application of that model to EPA's portion of the 2010 rulemaking for CO_2 and CAFE standards applicable to MYs 2012-2016.[108]~~ Among Mr. Rykowski's comments, a few specifically involve differences between these two models. Mr. Ryksowski recommended NHTSA's CAFE model replace its existing "effective cost" metric (used to compare available options to add specific technologies to specific vehicles) with a "ranking factor" used for the same purpose. As discussed below in Section VI, the model for today's final rule adopts this recommendation. He also states that (1) "EPA has developed a better way to isolate and reject cost ineffective combinations of technologies... [and] includes only these 50 or so technology combinations in their OMEGA model runs"; (2) "NHTSA's arbitrary and rigid designation of leader-follower vehicles for engine, transmission and platform level technologies unrealistically slows the rollout of technology into the new vehicle fleet"; (3) "the Volpe Model is not capable of reasonably simulating manufacturers' ability to utilize CO_2 credits to smooth the introduction of technology throughout their vehicle line-up"; and (4) "the Volpe Model is not designed to reflect the use of these [A/C leakage] technologies and refrigerants."[109]

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Separately, the California Air Resources Board and California Department of Justice engaged, respectively, Gary Rogers of Roush Industries and K.G. Duleep of H-D Systems (HDS), for supporting analyses. ~~Prior to joining Roush (in 2014), Mr. Rogers managed FEV North America, Inc., which supported EPA with technology demonstrations and cost studies referenced in the draft TAR.[110] Among other things, Mr. Duleep "served as the lead witness on~~

[104] *Id.* at 23.
[105] *Id.* at 24-25.
[106] *Id.* at 27.
[107] EDF, *NHTSA-2018-0067-12108*, Appendix B.
~~[108] See, e.g., EPA, Peer Review of the Optimization Model for Reducing Emissions of Greenhouse Gases from Automobiles (OMEGA) and EPA's Response to Comments, EPA-420-R-09-016, September 2009.~~
[109] EDF, *op. cit.*, at 73-75.
~~[110] Roush Industries, NHTSA-2018-0067-11984, at 2.~~

~~automotive technology issues for the States of California and Vermont in their defense of the California [carbon dioxide] emission standards for light vehicles."~~[111]

Mr. Rogers's analysis focuses primarily on the agencies' published analysis, but mentions that some engine "maps" (estimates—used as inputs to full vehicle simulation—of engine fuel consumption under a wide range of engine operating conditions) applied in Autonomie show greater fuel consumption benefits of turbocharging that those applied previously by EPA to EPA's ALPHA model, and these benefits could have caused NHTSA's CAFE model to estimate an unrealistically great tendency toward turbocharged engines (rather than high compression ratio engines).[112] Mr. Rogers also presents alternative examples of year-by-year technology application to specific vehicle models, contrasting these with year-by-year results from the agencies' NPRM analysis, concluding that "that the use of logical, unrestricted technology pathways, with incremental benefits supported by industry-accepted vehicle simulation and dynamic system optimization and calibration, together with publicly-defensible costs, allows cost-effective solutions to achieve target fuel economy levels which meet MY 2025 existing standards."[113]

Mr. Duleep's analysis also focuses primarily on the agencies' published analysis, but does mention that (1) "the Autonomie modeling assumes no engine change when drag and rolling resistance reductions are implemented, as well as no changes to the transmission gear ratios and axle ratios,… [but] the EPA ALPHA model adjusts for this effect"; (2) "baseline differences in fuel economy [between two manufacturers' different products using similar technologies] are carried for all future years and this exaggerates the differences in technology adoption requirements and costs between manufacturers; (3) "assumptions [that most technology changes are best applied as part of a vehicle redesign or freshening] result in unnecessary distortion in technology paths and may bias results of costs for different manufacturers"; and (4) that for the sample results shown for the Chevrolet Equinox "the publicly available EPA lumped parameter model (which was used to support the 2016 rulemaking) and 2016 TAR cost data… results in an estimate of attaining 52.2 mpg for a cost of $2110, which is less than half the cost estimated in the PRIA."[114]

Beyond these comments regarding differences between EPA's models and the Argonne and DOT models applied for the NPRM, these and other technical reviewers had many specific comments about the agencies' analysis for the NPRM, and these comments are discussed in detail below in Section VI.

Manufacturers, on the other hand, supported the agencies' use of Autonomie and the CAFE model rather than, in EPA's case, the ALPHA and OMEGA models. Expressly identifying the distinction between models and model inputs, Global Automakers stated that:

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The text appears to be casting aspersions on individuals, by name, and doing it by association with previous work done for US EPA (Mr. Rogers) or with state governments (Mr. Duleep). And if that is not the intent, then what is the intent of these very incomplete lists of credentials and past work?

For example, Mr. Rogers has also served on the board of the National Academy of Sciences, including on Committees which have provided advice to NHTSA, and Mr. Duleep has performed contractor work a number of times over the years for the U.S. Departement of Energy – why are the only aspects summarized here the work done in the past for US EPA, or for various State governments.

[111] H-D Systems, NHTSA-2018-0067-11985, at 8.
[112] Roush Industries, NHTSA-2018-0067-11984, at 17-21.
[113] Roush Industries, NHTSA-2018-0067-11984, at 17-30.
[114] H-D Systems, *op. cit.*, at 48, *et seq.*

> The agencies provided a new, updated analysis based on the most up-to-date data, using a proven and long-developed modeling tool, known as the Volpe model, and offering numerous options to best determine the right regulatory and policy path for ongoing fuel efficiency improvements in our nation. Now, all stakeholders have an opportunity to come to the table as part of the public process to provide input, data, and information to help shape the final rule.[115]
>
> This NPRM's use of a single model to evaluate alternative scenarios for both programs provides consistency in the technical analysis, and Global Automakers supports the Volpe model's use as it has proven to be a transparent and user-friendly option in this current analysis. The use of the Volpe model has allowed for a broad range of stakeholders, with varying degrees of technical expertise, to review the data inputs to provide feedback on this proposed rule. The Volpe model's accompanying documentation has historically provided a clear explanation of all sources of input and constraints critical to a transparent modeling process. Other inputs have come from modeling that is used widely by other sources, specifically the Autonomie model, allowing for a robust validation, review and reassessment.[116]

The Alliance commented, similarly, that "at least at this time, NHTSA's modeling systems are superior to EPA's" and "as such, we support the Agencies' decision to use NHTSA's modeling tools for this rulemaking and recommend that both Agencies continue on this path. We encourage Agencies to work together to provide input to the single common set of tools."[117]

Regarding the agencies' use of a revised version of Argonne's Autonomie model ~~rather than EPA's ALPHA model~~ relative to the version used for the 2016 Draft TAR, the Alliance commented that (1) "the benefits of virtually all technologies and their synergistic effects are now determined with full vehicle simulations"; (2) "vehicle categories have been increased to 10 to better recognize the range of 0–60 performance characteristics within each of the 5 previous categories, in recognition of the fact that many vehicles in the baseline fleet significantly exceeded the previously assumed 0–60 performance metrics. This provides better resolution of the baseline fleet and more accurate estimates of the benefits of technology….": (3) "new technologies (like advanced cylinder deactivation) are included, while unproven combinations (like Atkinson engines with 14:1 compression, cooled EGR, and cylinder deactivation in combination) have been removed"; (4) "Consistent with the recommendation of the National Academy of Sciences and manufacturers, gradeability has been included as a performance metric used in engine sizing. This helps prevent the inclusion of small displacement engines that are not commercially viable and that would artificially inflate fuel savings"; (5) "the Alliance believes NHTSA's tools (Autonomie/Volpe) are superior to EPA's (APLHA[sic]/LPM/OMEGA). This is not surprising since NHTSA's tools have had a significant head start in development….": (6) "the Autonomie model was developed at Argonne National Lab with funding from the Department of Energy going back to the PNGV (Partnership for Next Generation Vehicles) program in the 1990s. Autonomie was developed from the start to

Commented [A39]: REVISE: The list of examples that follows does not represent a comparision between the Autonomie and ALPHA models, but is instead a list of revisions made to the Autonomie modeling process. The inclusion of cylinder deac, greater resolution in vehicle performance characterization, performance assumptions more representative of the initial fleet, etc are all features of the ALPHA modeling process for the 2017 FD

[115] Global Automakers, NHTSA-2018-0067-12032, at 2.
[116] Global Automakers, NHTSA-2018-0067-12032, Attachment A, at A-12.
[117] Alliance, NHTSA-2018-0067-12073, at 134.

address the complex task of combining 2 power sources in a hybrid powertrain. It is a physics-based, forward looking, vehicle simulator, fully documented with available training", and (7) "EPA's ALPHA model is also a physics-based, forward looking, vehicle simulator. However, it has not been validated or used to simulate hybrid powertrains. The model has not been documented with any instructions making it difficult for users outside of EPA to run and interpret the model."[118]

Regarding the use of NHTSA's CAFE model rather than EPA's OMEGA model, the Alliance stated that (1) NHTSA's model appropriately differentiate between domestic and imported automobiles; (2) in NHTSA's model, "dynamic estimates of vehicle sales and scrappage in response to price changes replace unrealistic static sales and scrappage numbers"; (3) NHTSA's model "has new capability to perform [CO_2 emissions] analysis with [tailpipe CO_2] program flexibilities"; (4) "the baseline fleet [used in NHTSA's model] has been appropriately updated based on both public and manufacturer data to reflect the technologies already applied, particularly tire rolling resistance"; and (5) "some technologies have been appropriately restricted. For example, low rolling resistance tires are no longer allowed on performance vehicles, and aero improvements are limited to maximum levels of 15% for trucks and 10% for minivans."[119] The Alliance continued, noting that "NHTSA's Volpe model also predates EPA's OMEGA model. More importantly, the new Volpe model considers several factors that make its results more realistic."[120] As factors leading the Volpe model to produce results that are more realistic than those produced by OMEGA, the Alliance commented that (1) "The Volpe model includes estimates of the redesign and refresh schedules of vehicles based on historical trends, whereas the OMEGA model uses a fixed, and too short, time interval during which all vehicles are assumed to be fully redesigned....."; (2) "The Volpe model allows users to phase-in technology based on year of availability, platform technology sharing, phase-in caps, and to follow logical technology paths per vehicle....."; (3) "The Volpe model produces a year-by year analysis from the baseline model year through many years in the future, whereas the OMEGA model only analyzes a fixed time interval....."; (4) "The Volpe model recognizes that vehicles share platforms, engines, and transmissions, and that improvements to any one of them will likely extend to other vehicles that use them" whereas "The OMEGA model treats each vehicle as an independent entity....."; (5) "The Volpe model now includes sales and scrappage effects"; and (6) "The Volpe model is now capable of analyzing for CAFE and [tailpipe CO_2] compliance, each with unique program restrictions and flexibilities."[121] The Alliance also incorporated by reference concerns it raised regarding EPA's OMEGA-based analysis supporting EPA's proposed and prior final determinations.[122]

The Alliance further stated that "For all of the above reasons and to avoid duplicate efforts, the Alliance recommends that the Agencies continue to use DOT's Volpe and Autonomie modeling system, rather than continuing to develop two separate systems. EPA has

[118] *Id.* at 135.
[119] *Id.* at 134.
[120] *Id.* at 135.
[121] *Id.* at 135-136.
[122] *Id.* at 136.

demonstrated through supporting Volpe model code revisions and by supplying engine maps for use in the Autonomie model that their expertise can be properly represented in the rulemaking process without having to develop separate or new tools."[123]

Some individual manufacturers provided comments supporting and elaborating on the above comments by Global Automakers and the Alliance. For example, FCA commented that "the modeling performed by the agencies should illuminate the differences between the CAFE and [tailpipe CO_2 emissions] programs. This cannot be accomplished when each agency is using different tools and assumptions. Since we believe NHTSA possesses the better set of tools, we support both agencies using Autonomie for vehicle modeling and Volpe (CAFE) for fleet modeling."[124]

Honda stated that "The current version of the CAFE model is reasonably accurate in terms of technology efficiency, cost, and overall compliance considerations, and reflects a notable improvement over previous agency modeling efforts conducted over the past few years. We found the CAFE model's characterization of Honda's "baseline" fleet–critical modeling minutiae that provide a technical foundation of the agencies' analysis–to be highly accurate. We commend NHTSA and Volpe Center staff on these updates, as well as on the overall transparency of the model. The model's graphical user interface (GUI) makes it easier to run, model functionality is thoroughly documented, and the use of logical, traceable input and output files accommodates easy tracking of results."[125] Similarly, in an earlier presentation to the agencies, Honda included the following slide comparing EPA's OMEGA model to DOT's CAFE (Volpe) model, and making recommendations regarding future improvements to the latter:

[123] *Id.* at 136.
[124] FCA, NHTSA-2018-0067-11943, at 82.
[125] Honda, EPA-HQ-OAR-2018-0283, at 21-22.

Modeling Comparison – 2017

Issue	EPA / OMEGA	NHTSA / Volpe
GUI	n/a	Helpful
Documentation	Difficult for users to understand *(or buried in obscure docket)*	Very Good
Technology Interactions	LPM – "Black Box" Difficult to understand	Detailed & Transparent
Efficiency	>10% too optimistic "significantly inaccurate"	Reasonably Accurate
Baseline Input Databases	Independent Analysis	Proactively confirmed inputs with each OEM
Suggested Improvements		• Grid Emissions (upstream) • Turn-off early compliance strategy • Increase speed of runs • Learning based on cumulative volumes • Optional Turn off 30 months compliance • Add Roll05 and Roll15 as tech options

Figure IV-1 - Honda comparison of EPA and NHTSA fleet models[126]

Toyota, in addition to arguing that the agencies' application of model inputs (e.g., an analysis fleet based on MY 2016 compliance data) produced more realistic results than in the draft TAR and in EPA's former proposed and final determinations, also stressed the importance of the CAFE model's year-by-year accounting for product redesigns, stating that this produces more realistic results than the OMEGA-based results shown previously by EPA:

> The modeling now better accounts for factors that limit the rate at which new technologies enter and then diffuse through a manufacturer's fleet. Bringing new or improved vehicles and technologies to market is a several-year, capital-intensive undertaking. Once new designs are introduced, a period of stability is required so investments can be amortized. Vehicle and technology introductions are staggered over time to manage limited resources. Agency modeling now better recognizes the inherent constraints imposed by realities that dictate product cadence. We agree with the agencies' understanding that "the simulation of compliance actions that manufacturers might take is constrained by the pace at which new technologies can be applied in the new vehicle market", and we are encouraged to learn that "agency modeling can now account for the fact that individual vehicle models undergo significant redesigns relatively infrequently." The preamble correctly notes that manufacturers try to keep costs down by applying most major changes mainly during vehicle redesigns and more modest changes during product refresh, and that redesign cycles for vehicle models can range from six to ten years, and eight to ten-years for powertrains. This appreciation for standard business practice enables the modeling to more accurately capture the way

[126] Honda, NHTSA-2018-0067-12019, at 12.

> vehicles share engines, transmissions, and platforms. There are now more realistic limits placed on the number of engines and transmissions in a powertrain portfolio which better recognizes manufacturers must manage limited engineering resources and control supplier, production, and service costs. Technology sharing and inheritance between vehicle models tends to limit the rate of improvement in a manufacturer's fleet.[127]

These comments urging EPA to use NHTSA's CAFE model echo comments provided in response to a 2018 peer review of the model. While identifying various opportunities for improvement, peer reviewers expressed strong overall support for the CAFE model's technical approach and execution. For example, one reviewer, after offering many specific technical recommendations, concluded as follows:

> The model is impressive in its detail, and in the completeness of the input data that it uses. Although the model is complex, the reader is given a clear account of how variables are variously divided and combined to yield appropriate granularity and efficiency within the model. The model tracks well a simplified version of the real-world and manufacturing/design decisions. The progression of technology choices and cost benefit choices is clear and logical. In a few cases, the model simply explains a constraint, or a value assigned to a variable, without defending the choice of the value or commenting on real-world variability, but these are not substantive omissions. The model will lend itself well to future adaptation or addition of variables, technologies and pathways.[128]

Although the peer review charge focused solely on the CAFE model, another peer reviewer separately recommended that EPA "consider opportunities for EPA to use the output from the Volpe Model in place of their OMEGA Model output"[129].

More recently, in response to the NPRM, Dr. Julian Morris, an economist at George Washington University, commented extensively on the superiority of the agencies' NPRM analysis to previous analyses, offering the following overall assessment:

> I have assessed the plausibility of the analyses undertaken by NHTSA and EPA in relation to the proposed SAFE rule. I found that the agencies have undertaken a thorough—one might even say exemplary—analysis, improving considerably on earlier analyses undertaken by the agencies of previous rules relating to CAFE standards and [tailpipe CO_2] emission standards. Of particular note, the agencies included more realistic estimates of the rebound effect, developed a sophisticated model of the scrappage effect, and better accounted for various factors affecting vehicle fatality rates.[130]

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[127] Toyota, NHTSA-2018-0067-12098, Attachment 1, at 3 *et seq.*
[128] NHTSA, CAFE Model Peer Review, DOT HS 812 590, https://www.nhtsa.gov/document/cafe-model-peer-review, at 250.
[129] *Id.* at 287-288 and 304.
[130] Morris, J., OAR-2018-0283-4028, at 6-11.

The agencies carefully considered these and other comments regarding which models to apply when estimating potential impacts of each of the contemplated regulatory alternatives. For purposes of estimating the impacts of CAFE standards, even the coalition of environmental advocates observed that the CAFE model reflects EPCA's requirements. As discussed below in Section VI, EPCA imposes specific requirements not only on how CAFE standards are to be structured (e.g., including a minimum standard for domestic passenger cars), but also on how CAFE standards are to be evaluated (e.g., requiring that the potential to produce additional AFVs be set aside for the model years under consideration), and the CAFE model reflects these requirements, and ~~the agencies~~NHTSA considers the CAFE model to be the best available tool for CAFE rulemaking analysis. Regarding the use of Autonomie to construct fuel consumption (i.e., efficiency) inputs to the CAFE model, the agencies recognize that other vehicle simulation tools are available, including EPA's ~~recently-developed~~ ALPHA model. However, as also discussed in Section VI, Autonomie has a much longer history of development and refinement, and has been much more widely applied and validated. Moreover, Argonne experts have worked carefully for several years to develop methods for running large arrays of simulations expressly structured and calibrated for use in DOT's CAFE model. Therefore, the agencies consider Autonomie to be the best available tool for constructing such inputs to the CAFE model. While ~~the agencies have~~NHTSA has also carefully considered potential specific model refinements, as well as the merits of potential changes to model inputs and assumptions, none of these potential refinements and input have led ~~either agency~~NHTSA to reconsider using the CAFE model and Autonomie for CAFE rulemaking analysis.

Commented [A40]: CHANGE AS SHOWN: This statement (and the one is last sentence of this paragraph) is specific to NHTSA's decisions on using the CAFE model for CAFE rulemaking.

Commented [A41]: CHANGE AS SHOWN: The ALPHA model was developed nearly a decade ago, which is not "recently."

With respect to estimating the impacts of CO_2 standards, even though Argonne and the agencies have adapted Autonomie and the CAFE model to support the analysis of CO_2 standards, environmental groups, California, and other States would prefer that EPA use the models it developed during 2009-2018 for that purpose.[131] Arguments that EPA revert to its ALPHA and OMEGA models fall within three general categories: (1) arguments that EPA's models would have selected what commenters consider better (i.e., generally more stringent) standards, (2) arguments that EPA's models are technically superior, and (3) arguments that the law requires EPA use its own models.

The first of these arguments—that EPA's models would have selected better standards—conflates the analytical tool used to inform decision-making with the action of making the decision. As explained elsewhere in this document and as made repeatedly clear over the past several rulemakings, the CAFE model (or, for that matter, any model) neither sets standards nor dictates where and how to set standards; it simply informs as to the potential effects of setting different levels of standards. In this rulemaking, EPA has made its own decisions regarding what CO_2 standards would be appropriate under the CAA.

Commented [A42]: REVISE: This interpretation of the comment is non-reponsive. The argument by the enviros is that the CAFE model, and associated inputs, significantly inflates the costs of attaining specific standards. Since cost is a significant factor in the selection of final standards, it's not unreasonable to infer that estimating higher costs would result in a selection of less stringent standards. Pretending that the enviros think the CAFE model makes the decision rather than the Administrator is sidestepping the issue, as well as being needlessly insulting.

The third of these arguments—that EPA is legally required to use only models developed by its own staff—is also without merit. The CAA does not require the agency to create or use a specific model of its own creation in setting tailpipe CO_2 standards. The fact that EPA's

[131] The last-finalized versions of EPA's OMEGA model and ALPHA tools were published in 2016 and 2017, respectively.

decision may be informed by non-EPA-created models does not, in any way, constitute a delegation of its statutory power to set standards or decision-making authority.[132] Arguing to the contrary would suggest, for example, that EPA's decision would be invalid because it relied on EIA's Annual Energy Outlook for fuel prices for all of its regulatory actions rather than developing its own model for estimating future trends in fuel prices. Yet, all Federal agencies that have occasion to use forecasts of future fuel prices regularly (and appropriately) defer to EIA's expertise in this area and rely on EIA's NEMS-based analysis in the AEO, even when those same agencies are using EIA's forecasts to inform their own decision-making. Similarly, this argument would mean that the agencies could not rely on work done by contractors or other outside consultants, which is contrary to regular agency practice across the entirety of the Federal Government.

The specific claim here that use of the CAFE model instead of ALPHA and OMEGA is somehow illegitimate is similarly unpersuasive. The CAFE and CO_2 rules have, since *Massachusetts v. EPA*, all been issued as joint rulemakings, and, thus are the result of a collaboration between the two agencies. This was true when the rulemakings used separate models for the different programs and continues to be true in today's final rule, where the agencies take the next step in their collaborative approach by now using simply one model to simulate both programs. In 2007, immediately following this Supreme Court decision, the agencies worked together toward standards for model years 2011-2015, and EPA made use of the CAFE model for its work toward possible future CO_2 standards. That the agencies would need to continue the unnecessary and inefficient process of using two separate combinations of models as the joint National Program continues to mature, therefore, runs against the idea that the agencies, over time, would best combine resources to create an efficient and robust regulatory program. For the reasons discussed throughout today's final rule, the agencies have jointly determined that Autonomie and the CAFE model ~~have significant technical advantages and~~ are ~~therefore the more~~ appropriate models to use to support both analyses.

Commented [A43]: CHANGE AS SHOWN: EPA does not agree that the CAFE model "has significant technical advantages," but rather, we prefer to revert to the NPRM language that the CAFE model is "reasonable and appropriate" for use in the EPA's consideration of CO2 standards, given the discretion under the CAA.

Further, the fact that Autonomie and CAFE models were initially developed by DOE/Argonne and NHTSA does not mean that EPA has no role in either these models or their inputs. That is, the development process for CAFE and CO_2 standards inherently requires technical and policy examinations and deliberations between staff experts and decision-makers in both agencies. Such engagements are a healthy and important part of any rulemaking activity—and particularly so with joint rulemakings. The Supreme Court stated in *Massachusetts v. EPA* that: "The two obligations [to set CAFE standards under EPCA and to set tailpipe CO_2 emissions standards under the CAA] may overlap, but there is no reason to think the

[132] "[A] federal agency may turn to an outside entity for advice and policy recommendations, provided the agency makes the final decisions itself." U.S. Telecom. Ass'n v. FCC, 359 F.3d 554, 565-66 (D.C. Cir. 2004). To the extent commenters meant to suggest outside parties have a reliance interest in EPA using ALPHA and OMEGA to set standards, EPA and NHTSA do not agree a reliance interest is properly placed on an analytical methodology, which consistently evolves from rule to rule. Even if it were, all parties that closely examined ALPHA and OMEGA-based analyses in the past either also simultaneously closely examined CAFE and Autonomie-based analyses in the past, or were fully capable of doing so, and thus, should face no additional difficulty now they have only one set of models and inputs/outputs to examine.

two agencies cannot both administer their obligations and yet avoid inconsistency."[133] When agency experts consider analytical issues and agency decision-makers decide on policy, which is informed (albeit not dictated) by the outcome of that work, they are working together as the Court appears to have intended in 2007, even if legislators' intentions have varied in the decades since EPCA and the CAA have been in place.[134] Regulatory overlap necessarily involves deliberation, which can lead to a more balanced, reasonable, and improved analyses, and better regulatory outcomes. It did here. The existence of deliberation is not *per se* evidence of unreasonableness, even if some commenters believe a different or preferred policy outcome would or should have resulted.[135]

Over the 44 years since EPCA established the requirement for CAFE standards, NHTSA, EPA and DOE career staff have discussed, collaborated on, and debated engineering, economic, and other aspects of CAFE regulation, through focused meetings and projects, informal exchanges, publications, conferences and workshops, and rulemakings.

Part of this expanded exchange has involved full vehicle simulation. While tools such as PSAT (the DOE-sponsored simulation tool that predated Autonomie) were in use prior to 2007, including for discrete engineering studies supporting inputs to CAFE rulemaking analyses, these tools' information and computing requirements were such that NHTSA had determined (and DOE and EPA had concurred) that it was impractical to more fully integrate full vehicle simulation into rulemaking analyses. Since that time, computing capabilities have advanced dramatically, and the agencies now agree that such integration of full vehicle simulation—such as the large-scale exercise of Autonomie to produce inputs to the CAFE Model—can make for more robust CAFE and CO_2 rulemaking analysis. This is not to say, though, that experts always agree on all methods and inputs *involved with full vehicle simulation. Differences in approach* and inputs can lead to differences in results. For example, DOE/Argonne's Autonomie model simulates technologies in a discrete matter~~, whereas EPA's ALPHA model "lumps" various technologies together. Also, because ALPHA model lags in development compared to Autonomie, it spans a smaller range of the technologies, increasing the need to use other models must be used to fill in gaps.~~ These differences discussed in greater detail below in Section VI, and in the FRIA accompanying today's notice.

Moreover, DOE has for many years used Autonomie (and its precursor model, PSAT) to produce analysis supporting fuel economy-related research and development programs involving

Commented [A44]: REVISE: This statement is not correct. The author is seemingly mixing up the ALPHA model with the 'lumped parameter model'.

Commented [A45]: REVISE: This statement is not correct and is subjective. EPA can provide a list of a number of areas where the ALPHA model has capabilities that preceded Autonomie.

Commented [A46]: CHANGE AS SHOWN: This statement is not correct and is likely subjective. EPA can provide a list of a number of areas where the ALPHA model has capabilities that preceded Autonomie.

Commented [A47]: CHANGE AS SHOWN: This statement is not correct. The range of potential technology representation is a question of inputs, rather than the model itself.

[133] Massachusetts v. EPA, 549 U.S. 497, 532 (2007).

[134] For example, when wide-ranging amendments to the CAA were being debated, S. 1630 contained provisions that, if enacted, would have authorized automotive CO_2 emissions standards and prescribed specific average levels to be achieved by 1996 and 2000. In a letter to Senators, then-Administrator William K. Reilly noted that the Bill *"requires for the first time control of emissions of carbon dioxide; this is essentially a requirement to improve fuel efficiency"* and outlined four reasons the H.W. Bush Administration opposed the requirement, including that *"it is inappropriate to add this very complex issue to the Clean Air Act which is already full of complicated and controversial issues."* Reilly, W., Letter to U.S. Senators (January 26, 1990). The CAA amendments ultimately signed into law did not contain these or any other provisions regarding regulation of CO_2 emissions.

[135] *See, e.g.*, U.S. House of Representatives, Committee on Oversight and Government Reform, Staff Report, 112th Congress, "A Dismissal of Safety, Choice, and Cost: The Obama Administration's New Auto Regulations", August 10, 2012, at 19-21 and 33-34.

billions of dollars of public investment, and NHTSA's CAFE model with inputs from DOE/Argonne's Autonomie model has produced analysis supporting rulemaking under the CAA. In 2015, EPA proposed new tailpipe CO_2 standards for MY 2021-2027 heavy-duty pickups and vans, finalizing those standards in 2016. Supporting the NPRM and final rule, EPA relied on analysis implemented by NHTSA using NHTSA's CAFE model, and NHTSA used inputs developed by DOE/Argonne using DOE/Argonne's Autonomie model. CBD questioned this history, asserting that, "EPA conducted a separate analysis using a different iteration of the CAFE model rather than rely on the version which NHTSA used, again resulting and parallel but corroborative modeling results."[136] CBD's comment mischaracterizes EPA's actual use of the CAFE Model. As explained in the final rule, EPA's "Method B" analysis was developed as follows:

> In Method B, the CAFE model from the NPRM was used to project a pathway the industry could use to comply with each regulatory alternative, along with resultant impacts on per-vehicle costs. However, the MOVES model was used to calculate corresponding changes in total fuel consumption and annual emissions for pickups and vans in Method B. Additional calculations were performed to determine corresponding monetized program costs and benefits.[137]

In other words, ~~EPA technical staff used a previous version of~~of the NHTSA's CAFE Model was used to perform ~~the challenging~~ part of the analysis—that is, the part that involves accounting for manufacturers' fleets, accounting for available fuel-saving technologies, accounting for standards under consideration, and estimating manufacturers' potential responses to new standards—and used EPA's MOVES model to perform ~~comparatively straightforward~~ "downstream" calculations of fuel consumption and tailpipe emissions, and used spreadsheets to calculate even more straightforward calculations of program costs and benefits. While some stakeholders perceive these differences as evidencing a meaningfully independent approach, in fact, the EPA ~~staff's~~ analysis was, at its core, wholly dependent on NHTSA's CAFE Model, and on that model's use of Autonomie simulations.

~~Given the above, the only remaining argument for EPA to revert to its previously-developed models rather than relying on Autonomie and the CAFE model would be that the former are so technically superior to the latter that even model refinements and input changes cannot lead Autonomie and the CAFE model to produce appropriate and reasonable results for CO_2 rulemaking analysis.~~ As discussed below, having considered a wide range of technical differences, the agencies find that for this joint CAFE and tailpipe CO_2 emissions rulemaking analysis, the Autonomie and the CAFE models provide the best analytical combination for CAFE analysis, and an appropriate set of tools for CO2 analysis. As discussed below in Section VI, Autonomie not only has a longer and wider history of development and application, but also DOE/Argonne's interaction with automakers, supplier and academies on continuous bases had made individual sub-models and assumptions ~~more~~ robust. Argonne has also been using research from DOE's Vehicle Technology Office (VTO) at the same time to make continuous

Commented [A48]: CHANGE AS SHOWN: The CAA does not require such a "test" as is implied in this text in order to "revert back" to using a different set of modeling tools. EPA does not agree, and this sentence is unnecessary and unhelpful to our response. EPA has discretion to use appropriate analytical tools and has explained its choice. The rest of the response, with our comments, is sufficient and this extra sentence hurts the response more than it helps.

[136] CBD, *et al.*, 2018-0067-12000, Appendix A, at 27.
[137] 81 FR 73478, 73506-07 (October 25, 2016).

improvements in Autonomie.[138] ~~Also, while Autonomie uses engine maps as inputs, and EPA developed engine maps that it could have used for today's analysis, EPA declined to do so, because these engine maps had technical flaws, as discussed below in Section VI.~~

As also discussed below in Section VI, the CAFE model now accounts for some important CO_2 provisions that ~~EPA's OMEGA model cannot does not account for~~are responsive to comments from EDF. For example, the CAFE model estimates the potential that any given manufacturer might apply CO_2 compliance credits it has carried forward from some prior model year. ~~While the~~The EDF comments~~one commenter, Mr. Rykowski,~~ take~~s~~ issue with how the CAFE model handles credit banking.~~, they does not acknowledge that EPA's OMEGA model, lacking a year-by-year representation of compliance, is altogether incapable of~~does not accounting for credit banking.~~ Also, ~~although Mr. Rykowski's~~EDF's comments regarding A/C leakage and refrigerants are partially correct insofar as the CAFE model does not account for leakage-reducing technologies explicitly, ~~the comment is as applicable to OMEGA as it is to the CAFE model and, in any event~~however, data regarding which vehicles have which leakage-reducing technologies was not available for the MY 2016 fleet. Nevertheless, as discussed in Section VI, NHTSA has refined the CAFE model's accounting for the cost of leakage reduction technologies.

~~The agencies have also considered Mr. Rykowski's comments suggesting that using OMEGA would be preferable because, rather than selecting from hundreds of thousands of potential combinations of technologies, OMEGA includes only the "50 or so" combinations that EPA has already determined to be cost-effective. The "better way" of making this determination is also effectively a model, but the separation of this model from OMEGA is, as evidenced by manufacturers' comments, obfuscatory, especially in terms of revealing how specific vehicle model/configurations initial engineering properties are aligned with specific initial technology combinations. By using a full set of technology combinations, the CAFE model makes very clear how each vehicle model/configuration is assigned to a specific initial combination and, hence, how subsequently fuel consumption and cost changes are accounted for. Moreover, EPA's separation of "thinning" process from OMEGA's main compliance simulation makes sensitivity analysis difficult to implement, much less follow. The agencies find, therefore, that the CAFE model's approach of retaining a full set of vehicle simulation results throughout the compliance simulation to be technically superior and more transparent.~~

Regarding comments by Messrs. Duleep, Rogers, and Rykowski suggesting that the CAFE model, by tying most technology application to planned vehicle redesigns and freshening, is too restrictive, the agencies disagree. As illustrated by manufacturers' comments cited above, as reinforced by both extensive product planning information provided to the agencies, and as further reinforced by extensive publicly available information, manufacturers tend to not make major changes to a specific vehicle model/configuration in one model year, and then make further major changes to the same vehicle model/configuration the next model year. There is ample evidence that manufacturers strive to avoid such discontinuity, complexity, and waste, and in the agencies' view, while it is impossible to represent every manufacturer's decision-making

Commented [A49]: DELETE: This statement is not correct. The EPA Administrator has chosen to rely upon NHTSA's technical analysis, which includes use of engine maps developed by IAV and ANL. But EPA does not agree that the engine maps developed by EPA are unsuitable for use in a technical analysis due to technical flaws. This includes both maps used in prevous actions, as well as engine maps which EPA has generated more recently, in just the past 12 months.

Commented [A50]: CHANGE AS SHOWN: Edited to focus on comments directed at the CAFE model and that changes to the CAFE model have been made in response. There's no need to compare old CAFE model to old OMEGA model.

Commented [A51]: DELETE: This description of the OMEGA process is not factually correct. The "thinning" as referred to here, or package "ranking" in the OMEGA process, is complex but all details have been made public with every analysis done. Further, sensitivity analysis is still possible by starting at the beginning, ranking packages under the sensitivity parameters, and "thinning" to the most cost-effective set of packages applicable under those sensitivity parameters.

[138] U.S. DOE Benefits & Scenario Analysis publications is available at https://www.autonomie.net/publications/fuel_economy_report.html. Last accessed November 14, 2019.

process precisely and with certainty, the CAFE model's approach of using estimated product design schedules provides a realistic basis for estimating what manufacturers could practicably do. Also, the relevant inputs are simply inputs to the CAFE model, and if it is actually more realistic to assume that a manufacturer can change major technology on all of its products every year, the CAFE model can easily be operated with every model year designated as a redesign year for every product. ~~While this makes the CAFE model capable of operation in a less-realistic way, without a year-by-year representation that carries forward technologies between model years, the OMEGA model cannot be operated in a way that accounts for what the agencies consider to be very real product planning considerations.~~

However, having also considered Mr. Rykowski's comments about the CAFE model's "effective cost" metric, and having conducted extensive side-by-side testing within the context of other updates to the model and inputs, the agencies are satisfied that an alternative metric like that used in OMEGA leads to more optimal choices under most conditions.~~[139]~~ Therefore, NHTSA has revised the CAFE model accordingly, as discussed below in Section VI.

Commented [A52]: DELETE: EPA suggests deleting the footnote as it implies a side-by-side comparison with OMEGA which does not exist for the final rule analysis.

Section VI also addresses Mr. Rogers's comments on engine maps used as estimates to full vehicle simulation. In any event, because engine maps are inputs to full vehicle modeling and simulation, the relative merits of specific maps provide no basis to prefer one vehicle simulation modeling system over another. Similarly, Section VI also addresses Mr. Duleep's comments preferring EPA's prior approach, using ALPHA, of effectively assuming that a manufacturer would incur no additional cost by reoptimizing every powertrain to extract the full fuel economy potential of even the smallest incremental changes to aerodynamic drag and tire rolling resistance. Mr. Duleep implies that Autonomie is flawed because the NPRM analysis did not apply Autonomie in a way that makes such assumptions. The agencies discuss powertrain sizing and calibration in Section VI, and note here that such assumptions are not inherent to Autonomie; like engine maps, these are inputs to full vehicle simulation. Therefore, neither of these comments by Mr. Rogers and Mr. Duleep lead the agencies to find reason not to use Autonomie.

None of this is to say that Autonomie and the CAFE model as developed and applied for the NPRM left no room for improvement. In the NPRM and RIA, the agencies discussed plans to continue work in a range of specific technical areas, and invited comment on all aspects of the analysis. As discussed below in Chapter VI, the agencies received extensive comment on the published model, inputs, and analysis, both in response to the NPRM and, for newly-introduced modeling capabilities (estimation of sales, scrappage, and employment effects), in response to additional peer review conducted in 2019. The agencies have carefully considered these comments, refined various specific technical aspects of the CAFE model (like the "effective cost" metric mentioned above), and have also updated inputs to both Autonomie and the CAFE model. Especially given these refinements and updates, EPA maintains that for this final ~~CO_2~~ rulemaking analysis, Autonomie and the CAFE model are ~~technically superior to EPA's ALPHA and OMEGA models~~appropriate analytical tools to inform ~~the~~its decision on the level of the standards. Therefore, having the discretion to select among available, technically ~~available~~sound

~~[139] However, under some circumstances, such as high fuel prices, the "effective cost" metric produces less expensive choices than the metric used in OMEGA.~~

and appropriate methods for conducting rulemaking analysis, ~~and recognizing that models inform but do not make regulatory decisions~~, EPA has elected to rely ~~solely~~ on the Autonomie and CAFE models to produce today's analysis of regulatory alternatives for CO_2 standards.

Commented [A53]: CHANGE AS SHOWN: EPA does not agree that the CAFE modeling tools are "technically superior" to EPA's, but rather EPA has decided to use the CAFE tools for this final rule under his CAA discretion.

The following sections provide a brief technical overview of the CAFE model, including changes NHTSA made to the model since 2012, and differences between the current analysis, the analysis for the 2016 Draft TAR and for the 2017 Proposed Determination/2018 Final Determination, and the 2018 NPRM, before discussing inputs to the model and then diving more deeply into how the model works. For more information on the latter topic, see the CAFE model documentation, available in the docket for this rulemaking and on NHTSA's website.

1. What assumptions have changed since the 2012 final rule?

Any analysis of regulatory actions that will be implemented several years in the future, and whose benefits and costs accrue over decades, requires a large number of assumptions. Over such time horizons, many, if not most, of the relevant assumptions in such an analysis are inevitably uncertain.[140] The 2012 CAFE/CO_2 rule considered regulatory alternatives for model years through MY 2025 (17 model years after the 2008 market information that formed the basis of the analysis) that accrued costs and benefits into the 2060s. Not only was the new vehicle market in 2025 unlikely to resemble the market in 2008, but so, too, were fuel prices. It is natural, then, that each successive CAFE/CO_2 analysis should update assumptions to reflect better the current state of the world and the best current estimates of future conditions.[141] However, beyond the issue of unreliable projections about the future, a number of agency assertions have proven similarly problematic. In fact, Securing America's Energy Future (SAFE) stated in their comments on the NPRM:

> Although the agencies argue "circumstances have changed" and "analytical methods and inputs have been updated," a thorough analysis should provide a side-by-side comparison of the changing circumstances, methods, and inputs used to arrive at this determination… They represent a rapid, dramatic departure from the agencies' previous analyses, without time for careful review and consideration.[142]

We describe in detail (below) the changes to critical assumptions, perspectives, and modeling techniques that have created substantive differences between the current analysis and the analysis conducted in 2012 to support the final rule. To the greatest extent possible, we have calculated the impacts of these changes on the 2012 analysis.

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[140] As often stated, "It's difficult to make predictions, especially about the future." *See, e.g.*, https://quoteinvestigator.com/2013/10/20/no-predict/.

[141] *See, e.g.*, 77 FR 62785 (Oct. 15, 2012) ("If EPA initiates a rulemaking [to revise standards for MYs 2022-2025], it will be a joint rulemaking with NHTSA. …NHTSA's development of its proposal in that later rulemaking will include the making of economic and technology analyses and estimates that are appropriate for those model years and based on then-current information.").

[142] Securing America's Energy Future, NHTSA-2018-0067-12172, at 39.

a) The value of fuel savings

The value of fuel savings associated with the preferred alternative in the 2012 final rule is primarily a consequence of two assumptions[143]: the fuel price forecast and the assumed growth in fuel economy in the baseline alternative against which savings are measured. In the 2012 final rule, both of these assumptions combined to inflate the value of fuel savings beyond what was practical or realistic. In fact, as the value of fuel savings accounted for nearly 80% of the total benefits of the 2012 rule, changing either of these assumptions is consequential. But the two are complementary, and the combination of assumptions in the 2012 final rule distorted the value of fuel savings in the alternatives.

The first of these assumptions, fuel prices, was simply an artifact of the timing of the rule. Following recent periodic spikes in the national average gasoline price and continued volatility after the great recession, the fuel price forecast then produced by EIA (as part of AEO 2011) showed a steady march toward historically high, sustained gasoline prices in the United States. However, the actual series of fuel prices has skewed much lower. As it has turned out, the observed fuel price in the years between the 2012 final rule and this rule has frequently been lower than the "Low Oil Price" sensitivity case in the 2011 AEO, even when adjusted for inflation. The discrepancy in fuel prices is important to the discussion of differences between the current rule and the 2012 final rule, because that discrepancy leads in turn to differences in analytical outputs and thus to differences in what the agencies consider in assessing what levels of standards are reasonable, appropriate, and/or maximum feasible. Yet the agencies caution readers not to interpret this discrepancy as a reflection of negligence on the part of the agencies, or on the part of EIA. Long-term predictions are challenging and the fuel price projections in the 2012 rule were within the range of conventional wisdom *at the time*. However, it does suggest that the analytical basis for fuel economy and tailpipe CO_2 regulations set almost two decades into the future are ~~vulnerable to surprises~~subject to significant uncertainty, in some ways, and reinforces the value of being able to adjust course when critical assumptions are proven inaccurate. This value was codified in regulation when EPA bound itself to the mid-term evaluation process as part of the 2012 final rule.[144]

To illustrate this point clearly, substituting the current (and observed) fuel price forecast for the forecast used in the 2012 CAFE final rule creates a significant difference in the value of fuel savings. Even under identical discounting methods (see Section 2, below), and otherwise identical inputs in the 2012 version of the CAFE Model, the current (and historical) fuel price forecast reduces the value of fuel savings by *$150 billion* – from $525 billion to $375 billion (in 2009 dollars).

The second assumption employed in the 2012 (as well as the 2010) final rule, that new vehicle fuel economy never improves unless manufacturers are required to increase fuel economy in the new vehicle market by increasingly stringent regulations, is more problematic. Despite the extensive set of recent academic studies showing, as discussed in Section VI, that

Commented [A54]: REVISE: EPA suggests this be reframed to explain that current projections are *different* than those used in 2012. This implies that even in 2012 we believed the estimates to be unrealistic, which is not the case. It is only based on new projections that we realize the 2012 estimates were high.

Commented [A55]: REVISE: Same comment as above.

Commented [A56]: REVISE: EPA fuel price estimates for the 2012 FRM were based on the 2012AEO through 2035 and the AEO historical rate of change for post-2035. NHTSA's assumed fuel prices were different from EPA's due to the use of different AEO data and post-2035 projection.

Commented [A57]: CHANGE AS SHOWN: EPA suggests a more neutral and factual tone.

Commented [A58]: CHANGE AS SHOWN: The numbers shown here would not be applicable to EPA's GHG analysis for various reasons, including, as noted above, EPA used different fuel price projections than NHTSA for the 2012 FRM.

[143] The value of fuel savings is also affected by the rebound effect assumption, assumed lifetime VMT accumulation, and the simulated penetration of alternative fuel technologies. However, each of these ancillary factors is small compared to the impact of the two factors discussed in this subsection.
[144] *See* 40 CFR 86-1818-12(h).

consumers value at least *some* portion, and in some studies nearly *all*, of the potential fuel savings from higher levels of fuel economy at the time they purchase vehicles, the agencies assumed in past rulemakings that buyers of new vehicles would never purchase, and manufacturers would never supply, vehicles with higher fuel economy higher than those in the baseline (MY 2016 in the 2012 analysis), regardless of technology cost or prevailing fuel prices in future model years. In calendar year 2025, the 2012 final rule assumed gasoline would cost nearly $4.50/gallon in today's dollars, and continue to rise in subsequent years. Even recognizing that higher levels of fuel economy would be achieved under the augural/existing standards than without them, the assertion that fuel economy and CO_2 emissions would not improve beyond 2016 levels in the presence of nearly $5/gallon gasoline is not credible, particularly in light of the many public comments highlighting increased consumer demand for higher-fuel-economy vehicles during the gas price spike of 2008, when average U.S. prices briefly broke $4/gallon. In the 2012 final rule, this assumption – that fuel economy and emissions would never improve absent regulation - created a persistent gap in fuel economy between the baseline and augural standards that grew to 13 mpg (at the industry average, across all vehicles) by MY 2025.

By substituting the ~~more credible, but still conservative,~~ assumption that consumers are willing to purchase fuel economy improvements that pay for themselves with avoided fuel expenditures over the first 2.5 years[145] (identical to the assumption in this final rule's central analysis) the gap in industry average fuel economy between the baseline and augural scenarios narrows from 13 mpg in 2025 to 6 mpg in 2025. As a corollary, acknowledging that fuel economy would continue to improve in the baseline under the fuel price forecast used in the final rule erodes the value of fuel savings attributable to the preferred alternative. While each gallon is still worth as much as was assumed in 2012, fewer gallons are consumed in the baseline due to higher fuel economy levels in new vehicles. In particular, the number of gallons saved by the preferred alternative selected in 2012 drops from about 180 billion to 50 billion once we acknowledge the existence of even a moderate market for fuel economy.[146] The value of fuel savings is similarly eroded, as higher fuel prices lead to correspondingly higher demand for fuel economy even in the baseline – reducing the value of fuel savings from $525 billion to $140 billion.

The magnitude of the fuel economy improvement in the baseline is a consequence of both the fuel prices assumed in the 2012 rule (already discussed as being higher than both subsequent observed prices and current projections) and the assumed technology costs. In 2012, a number

[145] Greene, D.L. and Welch, J.G., "Impacts of fuel economy improvements on the distribution of income in the U.S.," Energy Policy, Volume 122, November 2018, pp. 528-41 (YOU GUYS, I CAN'T FIND THIS QUOTE IN THIS DOCUMENT "Four nationwide random sample surveys conducted between May 2004 and January 2013 produced payback period estimates of approximately three years, consistent with the manufacturers' perceptions.") (Cited by Consumers Union, CFA, and ACEEE, Docket NHTSA-2018-0067-11731, Attachment 4, [insert page number]).

[146] Readers should note that this is not an estimate of the total amount of fuel that will be consumed or not consumed by the fleet as a whole, but simply the amount of fuel that will be consumed or not consumed *as a direct result of the regulation*. As illustrated in Section VII, light-duty vehicls in the U.S. would continue to consume considerable quantities of fuel and emit considerable quantities of CO_2 even under the baseline/augural standards, and agencies' analysis shows that the standards finalized today will likely increase fuel consumption and CO_2 emissions by a small amount.

Commented [A59]: REVISE: This is an inaccurate characterization of the case made in the rulemaking. See 77 FR 62843: the basis for assuming no change in fuel economy was past evidence on fleet fuel economy, not assumptions about manufacturer or consumer behavior.

Commented [A60]: REVISE: It is unnecessary to argue, and EPA does not agree, that the analysis in the 2012 rule was not credible.The framing should simply be that different analytical decisions are being made for this rule, based on looking at the information in a different way, public comments, new data, etc.

Commented [A61]: REVISE: It may be worth noting the difference between consumer and producer behavior when gas prices spiked. Consumers had to change what vehicles they bought; automakers were not able to modify vehicles to make individual models more efficient. Unless automakers perceived that prices would continue to stay high, there isn't clear evidence that they would change their production plans to improve fuel economy.

Commented [A62]: REVISE: Incomplete footnote.

Commented [A63]: CHANGE AS SHOWN: As commented on later in this document, using 2.5 years of fuel savings is not well supported by academic research. It's well below estimates of mean or median from the literature, though it is within the (extremely wide) range of values. Its primary support is that it's the value automakers have claimed for consumer willingness to pay for fuel economy, even though literature on consumer behavior doesn't show much support for this value.

If both automakers & consumers considered even 2.5 years of fuel savings in their decisions, the past baseline would have had more fuel-saving technology than vehicles actually had. As demonstrated in the TAR, the 2012-16 standards led to more widespread use of existing technologies that led to net consumer savings, many with payback periods less than 2.5 years, without adverse effects on other attributes. So the market hadn't been providing those technologies before the standards.

To emphasize further, if automakers and consumers considered 2.5 years of fuel savings in their decisions, how could it be true that the 2017 initial fleet has any opportunity remaining for more technology adoption that pays back in 2.5years? Cost-learning might explain some additional tech adoption in the absence of standards, but in general the fact that techs with payback <2.5 years haven't already been adopted in 2017 is pretty strong counter-evidence against NHTSA's assumption for manufacturer response in a perfect, frictionless market.

of technologies were assumed to have negative incremental costs – meaning that applying those technologies to existing vehicles would both improve their fuel economy and reduce the cost to produce them. Asserting that the baseline would experience no improvement in fuel economy without regulation is equivalent to asserting that manufacturers, despite their status as profit maximizing entities, would not apply these cost-saving technologies unless forced to do so by regulation. While this issue is discussed in greater detail in Section VI, the combination of inexpensive (or free) technology and high fuel prices created a logically inconsistent perspective in the 2012 rule – where consumers never demanded additional fuel economy, despite high fuel costs, and manufacturers never supplied additional fuel economy, despite the availability of inexpensive (or cost saving) technology to do so.

Many commenters on earlier rules supported the assumption that fuel economy would not improve at all in the absence of standards. In fact, some commenters still support this position. For example, EDF commented to the NPRM that, "NHTSA set the Volpe model to project that, with CAFE standards remaining flat at MY 2020 levels through MY 2026, automakers would over-comply with the MY 2020 standards by 9 grams/mile of CO_2 for cars and 15 g/mi of CO_2 for light trucks during the 2029-2032 timeframe, plus 1%/year improvements beyond MY 2032. This assumption unreasonably obscures the impacts of the rollback and is not reflective of historical compliance performance."[147]

EDF is mistaken in two different ways: (1) by acknowledging the existence of a well-documented market for fuel economy, rather than erroneously inflating the benefits associated with increasing standards, this assumption serves to isolate the benefits actually attributable to each regulatory alternative, and ~~(2) it is, indeed, reflective of historical compliance performance. While we rely on the academic literature (and comments from companies that build and sell automobiles) to defend the assertion that a market for fuel economy exists, the industry's historical CAFE compliance performance is a matter of public record.[148] As shown in Figure IV-2, Figure IV-3, and Figure IV-4 for more than a decade, the industry average CAFE has exceeded the standard for each regulatory class – by several mpg during periods of high fuel prices.~~

Commented [A64]: REVISE: See above – that appears to have happened. Adoption of fuel-saving technologies was slow before the standards, and sped up greatly with the standards. See the Automotive Trends Report, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100W5C2.PDF?Dockey=P100W5C2.PDF . Chapter 4.

In other words, this comment does not address the findings of the draft TAR from the MTE.

Commented [A65]: REVISE: It is unnecessary to argue, and EPA does not agree, that the analysis in the 2012 rule was wrong. The framing should simply be that different analytical decisions are being made for this rule, based on looking at the information in a different way, based on public comments, new data, etc.

Commented [A66]: REVISE: See comments above about the available literature on willingess to pay for fuel economy. It's not supportable to frame the commenter as "erroneously inflating" benefits. If the market is functioning efficiently, as argued, there should be some sound explanation provided for why the MY 2017 fleet presently fails to contain all the technologies which will pay back in 2.5 years.

Commented [A67]: REVISE: For MYs after 2012, the presentation here showing achieved vs. required mpg by regulatory class does not demonstrate that consumers are willing to pay for FE beyond the standards. Manufactures can be expected to determine pricing and marketing strategies considering overall (car and truck combined) compliance situation. As a result, the over-compliance on the car fleets since the more stringent 2012 standards took effect can be attributed to the strategy of several OEM's to generate credits from car fleets to transfer to truck fleets or bank for future use.

Rather than showing the reg classes individually, a more appropriate presentation would be to show the fleet combined fuel economy relative to the fleet combined standards.

[147] EDF, NHTSA-2018-0067-11996, Comments to DEIS, at 4.

~~[148] Data from CAFE Public Information Center (PIC) – https://one.nhtsa.gov/cafe_pic/CAFE_PIC_Home.htm (last accessed 11/13/2019).~~

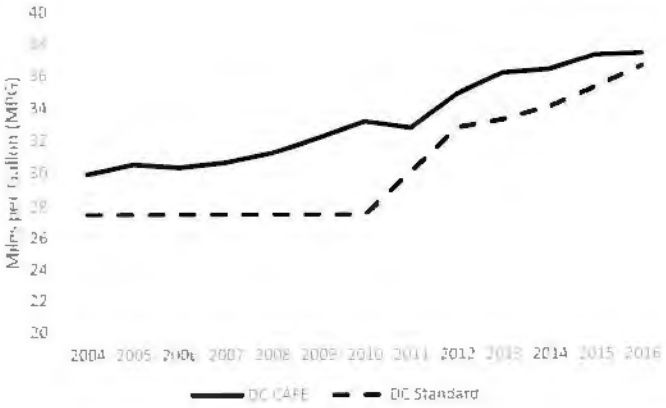


Figure IV-2 - Historical CAFE Compliance, Domestic Cars

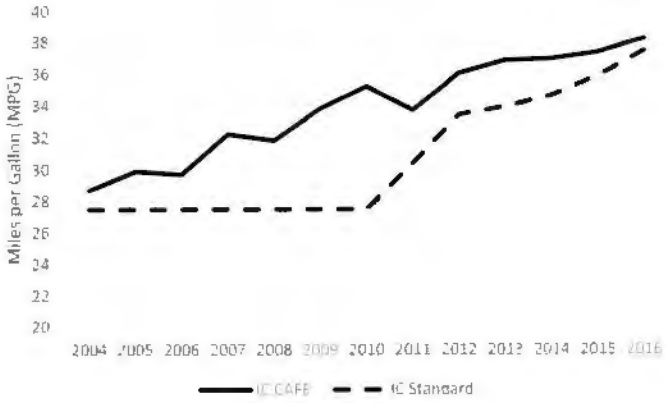
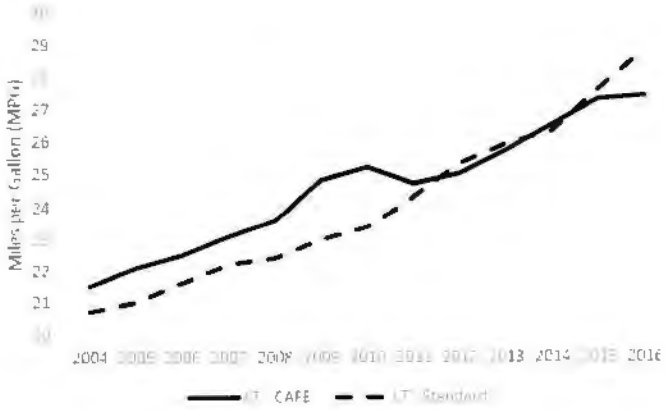


Figure IV-3 - Historical CAFE Compliance, Imported Cars



~~Figure IV-4 – Historical CAFE Compliance, Light Trucks~~

~~There is another feature of note in each of these figures. After several consecutive years of increasing standards, the achieved and required levels converge. When the standards began increasing again for passenger cars in 2011, the prior year had industry CAFE levels 5.6 mpg and 7.7 mpg in excess of their standards for domestic cars and imported cars, respectively. Yet, by 2016, the consecutive year-over-year increases had eroded the levels of over-compliance. Light trucks similarly exceeded their standard prior to increasing standards, which began in 2005. Yet, by 2011, after several consecutive years of stringency increases, the industry light-truck average CAFE was merely compliant with the rising standard.~~

While we have shown the impact of deviations from the 2012 rule assumptions individually, these two assumptions affect the value of fuel savings jointly. Replacing the fuel price forecast with the observed historical and current projected prices, and including any technology that pays for itself in the first 2.5 years of ownership through avoided fuel expenditures, reduces the value of fuel savings from $525 billion in the 2012 CAFE rule to $140 billion, all else equal. Interestingly, this reduction in the value of fuel savings is smaller than the result when assuming only that the desired payback period is nonzero. While it may seem counterintuitive, it is entirely consistent.

Commented [A68]: CHANGE AS SHOWN: The numbers shown here would not be applicable to EPA's GHG analysis for various reasons, including, as noted above, EPA used different fuel price projections than NHTSA for the 2012 FRM.

The number of gallons saved under the preferred alternative is actually higher when modifying both assumptions, compared to only modifying the payback period. Updating both assumptions leads to about 100 billion gallons saved by the preferred alternative in 2012, compared to only 50 billion from changing only the payback period, and 180 billion in the 2012 analysis. This occurs because the fuel economy in the baseline is lower when updating both the fuel price and the payback period – the gap between the augural standards and the baseline grows to 9 mpg, rather than only 6 mpg when updating only the payback period. Despite the existence of inexpensive technology in both cases, with lower fuel prices there are fewer opportunities to apply technology that will pay back quickly. As a consequence, the number of gallons saved by

the preferred alternative in 2012 increases – but each gallon saved is worth less because the price of fuel is lower.

b) Technology cost

While the methods used to identify cost-effective technologies to improve fuel economy in new vehicles have continuously evolved since 2012 (discussed further here and here), as have the estimated cost of individual technologies (discussed here), the inclusion of a market response in all scenarios (including the baseline) has changed the total technology cost associated with a given alternative. As discussed in Section IV.B.1.a), acknowledging the existence of a market for fuel economy leads to continued application of the most cost-effective technologies in the baseline – and in other less stringent alternatives – up to the point at which there are no remaining technologies whose cost is fully offset by the value of fuel saved in the first 30 months of ownership. The application of this market-driven technology has implications for fuel economy levels under lower stringencies (as discussed earlier), but also for the incremental technology cost associated with more stringent alternatives. As lower stringency alternatives (including the 2012 baseline) accrue more technology, the incremental cost of more stringent alternatives decreases.

By including a modest market for fuel economy, and preserving all other assumptions from the 2012 final rule, the incremental cost of technology attributable to the preferred alternative decreases from about $140 billion to about $72 billion. This significant reduction in technology cost is somewhat diminished by the associated reduction in the value of fuel savings (a decrease of $385 billion) when acknowledging the existence of a market for fuel economy. Another consequence of these changes is that the incremental cost of fuel economy technology is responsive to fuel price, as it should be. Under higher prices (as were assumed in 2012), consumers demand higher fuel economy in the new vehicle market. Under lower prices (as have occurred since the 2012 rule) consumers demand less fuel economy than would have been consistent with the fuel price assumptions in 2012.[149] Including a market response in the analysis ensures that, in each case, the cost of fuel economy technology within an alternative is consistent with those assumptions. Using the same fuel price forecast that supports this rule, and the same estimate of market demand for fuel economy, the incremental cost of technology in the preferred alternative would rise back up to about $110 billion.

c) The social cost of carbon (SCC) emissions

As discussed extensively in the NPRM, the agencies' perspective regarding the social cost of carbon has narrowed in focus. While the 2012 final rule considered the net present value of global damages resulting from carbon emitted by vehicles sold in the U.S. between MY 2009 and MY 2025, the NPRM (and this final rule) consider only those damages that occur to the United States and U.S. territories. As a result of this change in perspective, the value of estimated damages per-ton of carbon is correspondingly smaller. Had the 2012 final rule utilized

[149] This is why dozens of studies examining the ability of fuel taxes (and carbon taxes, which produce the same result for transportation fuels) to reduce CO_2 emissions have found cost-effective opportunities available for those pricing mechanisms.

the same perspective on the social cost of carbon, the benefits associated with the preferred alternative would have been about $11 billion, rather than $53 billion. However, the savings associated with carbon damages are a consequence of both the assumed cost per-ton of damages and the number of gallons of fuel saved. As discussed above, the gallons saved in the 2012 final rule were likely inflated as a result of both pessimistic fuel price forecasts and the assumption that no market exists for fuel economy improvements. Correcting the estimate of gallons saved from the preferred alternative in the 2012 rule and considering only the domestic social cost of carbon further reduces the savings in carbon damages to $6 billion.

Commented [A69]: REVISE: It is not accurate to infer degrees of optimism/pessimism into the assumnptions made by EIA reasearchers. In both the original and updated AEO reports, projections are made on the information available at the time.

d) Safety neutrality

In the 2012 final rule, the agencies showed a "safety neutral" compliance solution; that is, a compliance solution that produced no net increase in on-road fatalities for MYs 2017-2025 vehicles as a result of technology changes associated with the preferred alternative. In practice, safety neutrality was achieved by expressly limiting the availability of mass reduction technology to only those vehicles whose usage causes fewer fatalities with decreased mass. This result was discussed as one possible solution, where manufacturers chose technology solutions that limited the amount of mass reduction applied, and concentrated the application on vehicles that improve the safety of other vehicles on the roads (primarily by reducing the mass differential in collisions). However, it implicitly assumed that each and every manufacturer would leave cost-effective technologies unused on entire market segments of vehicles in order to preserve a safety neutral outcome at the fleet level for a given model year (or set of model years) whose useful lives stretched out as far as the 2060s. Removing these restrictions tells a different story.

When mass reduction technology, determined in the model to be a cost-effective solution (particularly in later model years, when more advanced levels of mass reduction were expected to be possible), is unrestricted in its application, the 2012 version of the CAFE Model chooses to apply it to vehicles in all segments. This has a small effect on technology costs, increasing compliance costs in the earliest years of the program by a couple billion dollars, and reducing compliance costs for MYs 2022 – 2025 by a couple billion dollars. However, the impact on safety outcomes is more pronounced.

Removing the restrictions on the application of mass reduction technology results in an additional 3,400 fatalities over the full lives of MYs 2009-2025 vehicles in the baseline,[150] and another 6,900 fatalities over those same vehicle lives under the preferred alternative. The result, a net increase of 3,500 fatalities under the preferred alternative relative to the baseline, also produces a net social cost of $18 billion. Our current treatment of both mass reduction technology, which can greatly improve the effectiveness of certain technology packages by reducing road load, and estimated fatalities, which now account for both general exposure (omitted in the 2012 final rule modeling) and fatality risk by age of the vehicle, further changes the story around mass reduction technology application for compliance and its relationship to on-road safety.

Commented [A70]: REVISE: This new analysis which is based (presumably?) on the 2012FRM models and inputs will need to be docketed to support these numbers. First impression is that the magnitude of the effect reported here seems improbable.

Alternatively, this side-case analysis could be deleted entirely, consistent with the argument made elsewhere in this preamble that 2012 FRM analysis is no longer valid.

[150] Relative to the continuation of vehicle mass from the 2008 model year carried forward into the future.

2. What methods have changed since the 2012 final rule?

Simulating how manufacturers might respond to CAFE/CO_2 standards requires information about existing products being offered for sale, as well as information about the costs and effectiveness of technologies that could be applied to those vehicles to bring the fleets in which they reside into compliance with a given set of standards. Following extensive additional work and consideration since the 2012 analysis, both agencies now use the CAFE Model to simulate these compliance decisions. This has several practical implications which are discussed in greater detail in Section VI. Briefly, this change represents a shift toward including a number of real-world production constraints—such as component sharing across a manufacturer's portfolio—and product cadence, where only a subset of vehicles in a given model year are redesigned (and thus eligible to receive fuel economy technology). Furthermore, the year-by-year accounting ensures a continuous evolution of a manufacturer's product portfolio that begins with the market data of an initial model year (model year 2017, in this analysis) and the last year for which compliance is simulated. Finally, the modeling approach ~~has migrated from one that relied on the simple product of single values to estimate technology effectiveness to a model that~~ relies on full vehicle simulation to determine the effectiveness of any combination of fuel economy technologies. The combination of these changes has greatly improved the realism of simulated vehicle fuel economy for combinations of technologies across vehicle systems and classes.

In addition to these changes to the portions of the analysis that represent the supply of fuel economy (by manufacturer, fleet, and model year) in the new vehicle market, this analysis contains changes to the representation of consumer demand for fuel economy. One such measure was discussed above—the notion that consumers will demand some amount of fuel economy improvement over time, consistent with technology costs and fuel prices. However, another deviation from the 2012 final rule analysis reflects overall demand for new vehicles. Across ten alternatives, ranging from the baseline (freezing future standards at 2016 levels) to scenarios that increased stringency by seven percent per year, from 2017 through 2025, the 2012 analysis showed no response in new vehicle sales, down to the individual model level. This implied that, regardless of changes to vehicle cost or attributes driven by stringency increases, no fewer (or possibly more) units of any single model would be sold in any year, in any alternative. Essentially, that analysis asserted that the new vehicle market does not respond, in any way, to average new vehicle prices across the alternatives—regardless of whether the incremental cost is $1,600/vehicle (as it was estimated to be under the preferred alternative) or nearly $4,000/vehicle (as it was in under the 7% alternative). Both the NPRM and this final rule, while not employing pricing models or full consumer choice models to address differentiated demand within brands or manufacturer portfolios, have incorporated a modeled sales response ~~that at least attempts correct the logical inconsistency of the earlier omission.~~

An important accounting method has also changed since the CAFE analysis in the 2012 final rule was published. At the time of that rule, the agencies used an approach to discounting, model-year analysis, that combined attributes of a private perspective and a social perspective in their respective benefit cost analyses. ~~This approach was logically inconsistent, and further reinforced some of the exaggerated estimates of fuel savings, social externalities, and technology costs described above.~~ The old model-year method discounted the value of all incremental

Commented [A71]: CHANGE AS SHOWN: This is incorrect if it alludes to EPA's vehicle simulation modeling in prior analysis (LPM then ALPHA). The text makes it sound like the previous rule estimated effectiveness for each techology individually, then just multiplied values. That has never been the case.

Commented [A72]: CHANGE AS SHOWN: It is unnecessary and incorrect to disparage the previous rule. "Omission" and "logical inconsistency" imply that the potential sales response wasn't considered. In fact, the potential for a sales resonse was considered, and the decision to hold sales constant across alternatives was a reasoned conclusion based on the avalable models.

Commented [A73]: REVISE: Amplifying comment below.

EPA held sales constant because of the uncertainty over the role of fuel economy in consumer vehicle sales purchases; further research (Greene et al. 2018) documents that great uncertainty. In addition, several recent papers (Haaf et al. 2014, 2016; Doremus et al. 2018) have found that holding market shares constant may provide better future predictions of shares than using a model to estimate consumer response. These issues were discussed in the TAR.

Thus, this discussion does not accurately characterize the reasoning for the 2012 FRM, nor does it address the support for that reasoning in subsequent literature and in the TAR.

Commented [A74]: DELETE: As previously commented, it is unnecessary to disparage the previous rule.

Commented [A75]: REVISE: This statement is somewhere between puzzling and wrong. Benefit-cost analysis is about net benefits to society; it is not required, or typically expected, to distinguish between private & social perspectives. The latter is the subject of distributional analysis.

quantities, whether categorized as benefits or costs, to the model year of the vehicle to which they accrued. (EPA uses, not model-year analysis, but calendar-year analysis for the central analysis in its rulemakings, which avoids this problem.) This approach is largely acceptable for use in a private benefit cost analysis, where the costs and benefits accrue to the buyer of a new vehicle (in the case of this policy) who weighs their discounted present values at the time of purchase. However, the private perspective would not include any costs or benefits that are external to the buyer (e.g., congestion or the social cost of carbon emissions). For an analysis that compares benefits and costs from the social perspective, attempting to estimate the relative value of a policy to all of society rather than just buyers of new vehicles, this approach is more problematic.

The model-year discounting approach that provided the central analysis in ~~the~~ NHTSA's 2012 final rule was particularly distortionary for a few reasons. The fact that benefits and costs occurred over long time periods in the 2012 rule, and the standards isolated the most aggressive stringency increases in the latter years of the program, served to allow benefits that occurred in 2025 (for example) to enter the accounting without being discounted, provided that they accrued to the affected vehicles during their first year of ownership. In a setting where numerous inputs (e.g., fuel price and social cost of carbon) increase over time, benefits were able to grow faster than the discount rate in some cases~~—essentially making them infinite~~. The interpretation of discounting for externalities was equally problematic. For example, ~~the~~ NHTSA's discounting approach in the final rule would have counted a ton of CO_2 not emitted in CY 2025 in multiple ways, despite the fact that the social cost of carbon emissions was inherently tied to the calendar year in which the emissions occurred. Were the ton avoided by a MY 2020 vehicle, which would have been five years old in CY 2025, the value of that ton would have been the social cost of carbon times 0.86, but would have been undiscounted if that same ton had been saved by a MY 2025 vehicle in its initial year of usage.

This model-year approach was initially updated in the 2016 Draft TAR to be more consistent with common economic practice for benefit-cost analysis, and this analysis continues that approach. In the social perspective, all benefits and costs for each model-year are discounted back to the decision year based on the calendar year in which they occur. Had we utilized such an approach in the 2012 final rule, net benefits of the model-year analysis would have been reduced by about 20 percent, from $465 billion to $374 billion—not accounting for any of the other adjustments discussed above.

3. How have conditions changed since the 2012 final rule was published?

The 2012 final rule relied on market and compliance information from model year 2008 to establish standards for model years 2017 2025. However, in the intervening years, both the market and the industry's compliance positions have evolved. The industry has undergone a significant degree of change since the MY 2008 fleet on which the 2012FR was based. Entire brands (Pontiac, Oldsmobile, Saturn, Hummer, Mercury, etc.) and companies (Saab, Suzuki, Lotus) have exited the U.S. market, while others (most notably Tesla) have emerged. Several dozen nameplates have been retired and dozens of other created in that time. Overall, the industry has offered a diverse set of vehicle models that have generally higher fuel economy than the prior generation, and an ever-increasing set of alternative fuel powertrains.

Commented [A76]: CHANGE AS SHOWN: EPA has typically used calendar-year analysis, which is consistent with EPA's Guidelines for Preparing Economic Analyses.

Commented [A77]: CHANGE AS SHOWN AND REVISE: This appears to be an argument against the use of model-year analysis. Yet this preamble presents model-year analysis, when a better method (calendar-year analysis) is available.

Commented [A78]: CHANGE AS SHOWN AND REVISE: EPA didn't do this in its central analysis, which was based on calendar-years; all values were discounted back to the same year.

Commented [A79]: CHANGE AS SHOWN: Benefits were finite in the rule.

Commented [A80]: REVISE: Again, this may speak to NHTSA's MY analysis in the 2012 FRM, but this was not EPA's method for its central CY analysis, in which all future-year emissions were discounted back to the same base year.

Commented [A81]: CHANGE AS SHOWN: Model-year analysis is not "consistent with common economic practice for benefit-cost analysis," which uses a calendar-year approach. See, e.g., Chapter 6 of EPA's Guidelines for Preparing Economic Analyses (https://www.epa.gov/sites/production/files/2017-09/documents/ee-0568-06.pdf), and OMB Circular A-4 ("The beginning point for your stream of estimates should be the year in which the final rule will begin to have effects, even if that is expected to be some time in the future. The ending point should be far enough in the future to encompass all the significant benefits and costs likely to result from the rule."

As Table IV-1Table IV-1 shows, alternative powertrains have steadily increased under CAFE/CO_2 regulations. Under the standards between 2011 and 2018, the number of electric vehicle offerings in the market has increased from 1 model to 57 models (inclusive of all plug-in vehicles that are rated for use on the highway), and hybrids (like the Toyota Prius) have increased from 20 models to 43 models based on data from DOE's Alternative Fuels Data Center. Fuel efficient diesel vehicles have similarly been on the rise in that period, more than doubling the number of offerings. Flexible fuel vehicles (FFVs), capable of operating on both gasoline and E85 remain readily available in the market, but have been excluded from the table due to both their lower fuel economy and demonstrated consumer reluctance to operate FFVs on E85. They have historically been used to improve a manufacturer's compliance position, rather than other alternative fuel systems that reduce fuel consumption and save buyers money.

Table IV-1 - Alternative Fuel Vehicle Offerings

Model Year	Diesel	Electric	Hybrid	Hydrogen	Total
2008	6	1	16	0	23
2009	12	1	19	0	32
2010	14	1	20	0	35
2011	16	2	29	0	47
2012	17	6	31	1	55
2013	22	15	38	1	76
2014	35	16	43	2	96
2015	39	27	46	3	115
2016	29	29	31	3	92
2017	21	51	44	2	118
2018	38	57	43	2	140

*EVs include plug-in HEVs, but do not include Neighborhood Electric Vehicles, Low Speed Electric Vehicles, or two-wheeled electric vehicles. Only full-sized vehicles sold in the U.S. and capable of 60mph are listed.

Not only have alternative powertrain options proliferated since the 2012 FR, the average fuel economy of new vehicles within each body style has increased. However, the more dramatic effect may lie in the *range* of fuel economies available within each body style. Figure IV-2Figure IV-2 shows the distribution of new vehicle fuel economy (in miles per gallon equivalent) by body style for MYs 2008, 2016, and 2020 (simulated). Each box represents the 25th and 75th percentiles, where 25 and 75 percent of new models offered are less fuel efficient than that level. Not only has the median fuel economy improved (the median shows the point at which 50 percent of new models are less efficient) under the CAFE/CO_2 programs, but the range of available fuel economies

(determined by the length of the boxes and their whiskers) has increased as well. For example, the 25th percentile of pickup truck fuel economy in 2020 is expected to be significantly more efficient than 75 percent of the pickups offered in 2008. In MY 2008, there were only a few SUVs offered with rated fuel economies above 34MPG. By MY 2020 almost half of the SUVs offered will have higher fuel economy ratings—with almost 20 percent of offerings exceeding 40MPG.

The improvement in passenger car styles has been no less dramatic. As with the other styles, the range of available fuel economies has increased under the CAFE/CO_2 programs and the distribution of available fuel economies skewed higher—with 40 percent of MY 2020 models exceeding 40MPG. The attribute-based standards are designed to encourage manufacturers to improve vehicle fuel economy across their portfolios, and they have clearly done so. Not only have the higher ends of the distributions increased, the lower ends in all body styles have improved as well, where the least fuel efficient 25 percent of vehicles offered in MY 2016 (and simulated in 2020) are more fuel efficient than the most efficient 25 percent of vehicles offered in MY 2008.

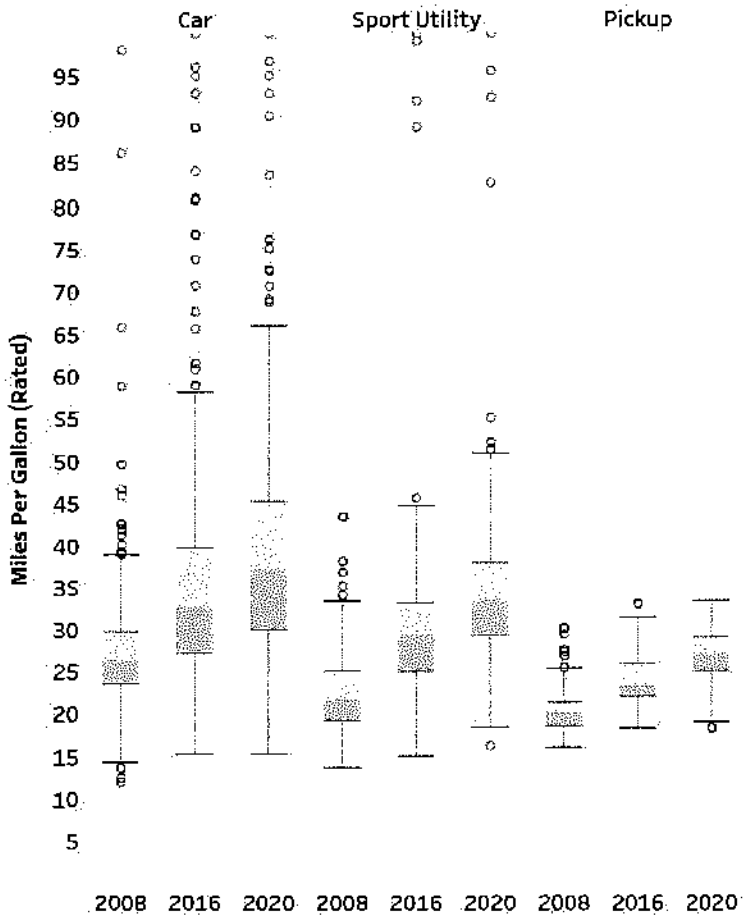


Figure IV-2 - Fuel Economy Distribution of New Vehicle Market by Body Style

Some commenters have argued that consumers will be harmed by any set of standards lower than the baseline (augural) standards because buyers of new vehicles will be forced to spend more on fuel than they would have under the augural standards. However, as Figure IV-2Figure IV-2 shows, the range of fuel economies available in the new market is already sufficient to suit the needs of buyers who desire greater fuel economy rather than interior volume or some other attributes. Full size pickup trucks now rely on smaller turbocharged engines paired with 8 and 10-speed transmissions and some mild electrification. Buyers looking to transport a large family can choose to purchase a plug-in hybrid minivan. There were 57 electric models available in 2018, and hybrid powertrains are no longer limited to compact cars (as they

once were). Buyers can choose hybrid SUVs with all-wheel and four-wheel drive. While these kinds of highly efficient options were largely absent from some body styles in MY 2008, this is no longer the case. ~~If the consumer acceptance of high MPG vehicles has lagged behind the supply of them in the marketplace, consumers are likely trading off improvements in other desirable attributes against further improvements in fuel economy.~~

Commented [A82]: DELETE: This reads as a hypothetical, in which case it's misleading to include here, and should be removed. If it's meant to be a statement of fact, we have not found any systemic impact on consumer acceptance from efficiency technologies. (Note that the skewed distribution in Figure IV-5 is the result of including BEVs, which are qualitatively different from other vehicles, and would not typically be compared from a consumer's perspective on an mpg-equiv. measure)

Manufacturers have accomplished a portfolio-wide improvement by improving the combustion efficiency of engines (through direct injection and turbocharging), migrating from four and five speed transmissions to 8 and 10 speed transmissions, and electrifying to varying degrees. All of this has increased both production costs and fuel efficiency during a period of economic expansion and low energy prices. While the vehicles offered for sale have increased significantly in efficiency between MY 2008 and MY 2020, the sales-weighted average fuel economy has achieved less improvement. Despite stringency increases of about five percent (year-over-year) between 2012 and 2016, the sales-weighted average fuel economy increased marginally. Figure IV-3Figure IV-3 shows an initial increase in average new vehicle fuel economy, followed by relative stagnation as fuel prices fell and remained low.[151] It is worth noting that average new vehicle fuel economy observed a brief spike during the year that the Tesla Model 3 was introduced (as a consequence of strong initial sales volumes, as pre-orders were satisfied, and fuel economy ratings that are significantly higher than the industry average), and have settled around 27.5 MPG in Fall 2019.

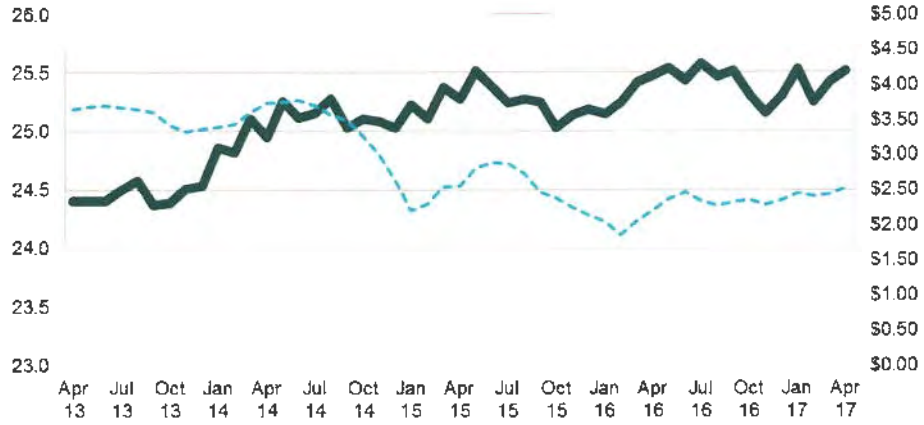


Figure IV-3 - Ward's Automotive Fuel Economy Index, April 2013 – April 2017

In their NPRM comments, manufacturers expressed concern that CAFE standards had already increased to the point where the price increases necessary to recoup manufacturers'

[151] Ward's Automotive, https://www.wardsauto.com/industry/fuel-economy-index-shows-slow-improvement-april. Last accessed Dec. 13, 2019.

increased costs for providing further increases in fuel economy outweigh the value of fuel savings.[152,153] The agencies do not agree that this point has already been reached by previous stringency increases, but acknowledge the reality of diminishing marginal returns to improvements in fuel economy. A driver with a 40MPG vehicle uses about 300 gallons of fuel per year. Increasing the fuel economy of that vehicle to 50MPG, a 25 percent increase, would likely be over $1000 in additional technology cost. However, that driver would only save 25 percent of their annual fuel consumption, or 75 gallons out of 300 gallons. Even at $3 gallon, higher than the current national average, that represents $225 per year in fuel savings. That means that the buyer's $1000 investment in additional fuel economy pays back in just under 4.5 years (undiscounted). The agencies' respective programs have created greater access to high MPG vehicles in all classes and encouraged the proliferation of alternative fuels and powertrains. But if the value of the fuel savings is insufficient to motivate buyers to invest in ever greater levels of fuel economy, manufacturers will face challenges in the market.

With the fuel price increases fresh in the minds of consumers, and the great recession only recently passed, the CAFE stringency increases that began *in 2011* (and subsequent CAFE/CO_2 stringency increases after EPA's program was first ~~enforced~~ established in MY 2012) had something of a head start. As through illustrate, the standards were *not* binding in MY 2011—even manufacturers that had historically paid civil penalties were earning credits for overcompliance. It took two years of stringency increase to catch up to the CAFE levels already present in MY 2011. However, seven consecutive years of increases for passenger cars and a decade of increases for light trucks has changed the credit situation. Figure IV-4Figure IV-4 shows CAFE credit performance for regulated fleets —the solid line represents the number of fleets generating shortfalls and the dashed line represents the number of fleets earning credits in each model year.

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[152] NHTSA-2018-0067-12064-25
[153] NHTSA-2018-0067-12073-2

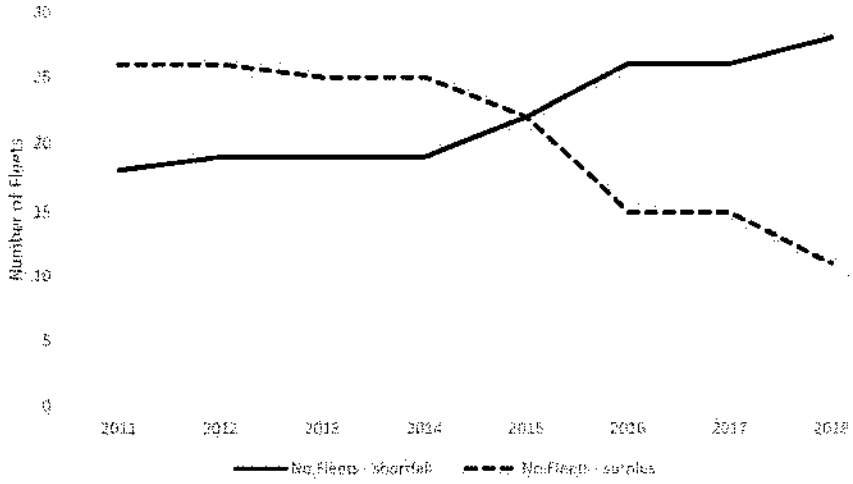

Figure IV-4 - Industry CAFE Credit Performance Over Time

Fewer than half as many fleets earned surplus credits for over-compliance in MY 2017 compared to MY 2011—and this trend is persistent. The story varies from one manufacturer to another, but it seems sufficient to state the obvious—when the agencies conducted the analysis to establish standards through MY 2025 back in 2012, most (if not all) manufacturers had healthy credit positions. That is no longer the case, and each successive increase requires many fleets to not only achieve the new level from the resulting increase, but to resolve deficits from the prior year as well. The large sums of credits, which last five years under both programs, have allowed most manufacturers to resolve shortfalls. But the light truck fleet, in particular, has a dwindling supply of credits available for purchase or trade. The CO_2 program has a provision that allows credits earned during the early years of over-compliance to be applied through MY 2021. This has reduced the compliance burden in the last several years, as intended, but will not mitigate the compliance challenges some OEMs would face if the baseline standards remained in place and energy prices persisted at current levels.

Table IV-2 - CAFE Credits (in millions) Earned by Manufacturer, Fleet, and Model Year

Manufacturer	Fleet	MY2010	MY2011	MY2012	MY2013	MY2014	MY2015	MY2016	MY2017
BMW	PC	1.9	(1.3)	(0.4)	(0.3)	4.2	(1.0)	(6.4)	(4.8)
Daimler	PC	(2.2)	(5.6)	(5.2)	(3.7)	(2.8)	(1.8)	(4.2)	(5.6)
FCA	PC	2.6	3.0	(4.2)	(1.2)	(11.9)	(9.3)	(25.7)	(22.2)
Ford	PC	36.4	24.1	26.1	40.6	30.1	7.0	(3.0)	(22.4)

GM	PC	27.6	20.0	7.2	10.9	11.0	(8.5)	(17.8)	13.2
Honda	PC	64.7	30.2	48.0	54.0	41.7	53.9	50.3	43.0
Hyundai	PC	27.6	28.3	24.4	46.7	10.2	9.7	9.1	(4.4)
JLR	PC	(0.4)	(0.7)	(0.8)	(0.8)	(0.7)	(0.9)	(1.1)	(1.4)
Kia	PC	20.0	15.1	8.0	11.6	(3.0)	(6.3)	(2.8)	(0.5)
Mazda	PC	13.4	5.6	8.5	7.6	15.4	13.3	14.7	0.9
Mitsubishi	PC	1.9	1.8	0.3	0.1	2.0	3.1	(0.5)	2.2
Nissan	PC	-	23.0	16.1	52.5	49.9	68.3	32.3	12.1
Subaru	PC	0.5	(0.4)	1.8	1.9	0.9	1.5	(1.7)	(5.5)
Tesla	PC	-	-	7.2	43.9	43.9	68.4	131.4	255.1
Toyota	PC	169.0	71.6	99.1	84.3	85.0	58.7	34.8	20.9
Volvo	PC	0.1	(0.5)	(1.4)	(1.3)	(0.5)	0.2	-	(0.2)
VW	PC	15.9	8.6	(1.4)	1.0	4.4	3.7	1.3	(24.3)
BMW	LT	0.0	(0.1)	(0.7)	(1.2)	0.8	0.1	(1.1)	(0.5)
Daimler	LT	(1.5)	(3.0)	(1.7)	(1.1)	(1.5)	(3.1)	(2.9)	(4.5)
FCA	LT	6.4	(2.5)	(11.9)	(11.1)	(11.6)	(24.1)	(35.5)	(24.7)
Ford	LT	7.6	5.8	0.7	3.7	(2.1)	-	(14.6)	(10.7)
GM	LT	23.3	5.4	(0.9)	(4.6)	10.5	-	(23.0)	(20.5)
Honda	LT	16.3	4.8	6.9	4.7	9.8	12.8	5.9	11.4
Hyundai	LT	5.6	1.1	0.3	(0.1)	(0.5)	(1.0)	(0.8)	(2.3)
JLR	LT	(1.4)	(3.0)	(2.9)	(3.0)	(1.3)	(1.5)	(4.7)	(2.7)
Kia	LT	0.6	2.3	0.8	0.1	(0.3)	(0.3)	(3.9)	(3.8)
Mazda	LT	3.2	(0.3)	0.4	1.4	2.0	1.3	4.3	1.0
Mitsubishi	LT	0.8	0.3	0.4	0.5	1.3	1.3	1.0	0.8
Nissan	LT	4.2	(0.9)	(5.6)	0.4	0.8	4.3	-	(5.1)
Subaru	LT	11.3	7.9	3.4	8.7	19.6	24.2	16.1	19.4
Toyota	LT	22.4	7.0	(1.4)	(4.6)	(7.0)	(19.2)	(26.6)	(11.2)
Volvo	LT	(0.1)	(0.4)	(0.3)	(0.8)	(0.5)	(0.8)	-	0.9
VW	LT	0.8	0.7	0.1	0.8	0.6	(0.8)	(2.0)	(2.9)

Table IV-2Table IV-2 shows the credits earned by each manufacturer over time[154]. As the table shows, when the agencies considered future standards in 2012, most manufacturers were earning credits in at least one fleet. However, the bold values show years with deficits and

[154] MY 2017 values represent estimated earned credits based on MY 2017 final compliance data.

even some manufacturers who started out in strong positions, such as Ford's passenger car fleet, have seen growing deficits in recent years. While the initial banks for early-action years eases the burden of CO_2 compliance for many OEMs, the year-to-year compliance story is similar to CAFE, see Table IV-3Table IV-3.

Table IV-3 - CO_2 Credits (MMT) Earned by Manufacturer and Model Year

Manufacturer	MY2009-2011	MY2012	MY2013	MY2014	MY2015	MY2016	MY2017
BMW	1.3	**(0.1)**	0.0	1.1	0.0	**(1.0)**	0.4
Daimler	0.4	**(0.7)**	**(0.3)**	**(0.4)**	**(0.6)**	**(1.6)**	**(2.3)**
FCA	10.4	**(1.2)**	**(1.0)**	**(0.0)**	**(1.5)**	**(11.8)**	**(9.1)**
Ford	16.1	4.8	8.2	4.8	2.0	**(8.1)**	**(6.1)**
GM	25.5	3.6	2.4	7.8	0.4	**(13.2)**	**(3.2)**
Honda	35.8	7.9	7.3	6.5	7.2	6.2	7.5
Hyundai	14.0	3.5	5.8	1.1	0.6	0.2	**(2.0)**
JLR	-	**(0.5)**	**(0.7)**	**(0.1)**	0.1	**(1.1)**	**(0.7)**
Kia	10.4	1.3	1.3	**(0.8)**	**(1.6)**	**(2.2)**	**(0.9)**
Mazda	5.5	0.7	0.8	1.5	1.0	1.2	**(0.1)**
Mitsubishi	1.4	0.1	0.1	0.4	0.3	0.1	0.3
Nissan	18.1	**(0.7)**	5.2	4.9	8.1	2.9	**(0.3)**
Subaru	5.8	0.6	1.4	2.9	3.0	1.2	2.4
Tesla	0.0	0.2	1.0	1.0	1.3	2.5	2.4
Toyota	80.4	13.2	9.9	9.8	2.6	**(4.7)**	**(3.0)**
Volvo	0.7	**(0.2)**	**(0.3)**	**(0.2)**	0.0	**(0.0)**	0.2
VW	6.4	**(0.4)**	0.0	0.1	**(0.4)**	**(1.9)**	**(4.1)**

Credit position and shortfall rates clearly illustrate ~~how manufacturers are complying, or failing to comply, with the~~manufacture fleet performance relative to the standards. Recognizing that manufacturers plan compliance over several model years at any given time, sporadic shortfalls may not be evidence of undue difficulty, but sustained, widespread, growing shortfalls should probably be viewed as evidence that standards previously believed to be manageable might no longer be so. While NHTSA is prohibited by statute from considering availability of credits (and thus, size of credit banks) in determining maximum feasible standards, it does

Commented [AB4]: CHANGE AS SHOWN: It is not accurate to equate the credit inflow/outflow in a given year with compliance/non-compliance state since year-over-year credit carry-forward/carry-back is an integral part of the compliance determination.

consider shortfalls as part of its determination. EPA has no such prohibition under the CAA and is free to consider both credits and shortfalls.

V. Regulatory alternatives considered

Agencies typically consider regulatory alternatives in proposals as a way of evaluating the comparative effects of different potential ways of accomplishing their desired goal. NEPA requires agencies (in this case, NHTSA, but not EPA) to compare the potential environmental impacts of their proposed actions to those of a reasonable range of alternatives. Executive Orders 12866 and 13563 and OMB Circular A-4 also encourage agencies to evaluate regulatory alternatives in their rulemaking analyses. Alternatives analysis begins with a "no-action" alternative, typically described as what would occur in the absence of any regulatory action. This final rule, like the proposal, includes a no-action alternative, described below, as well as seven "action alternatives." The final standards may, in places, be referred to as the "preferred alternative," which is NEPA parlance, but NHTSA and EPA intend "final standards" and "preferred alternative" to be used interchangeably for purposes of this rulemaking.

In the proposal, NHTSA and EPA defined the different regulatory alternatives (other than the no-action alternative) in terms of percent-increases in CAFE and CO_2 stringency from year to year. Percent increases in stringency referred to changes in the standards year over year – as in, standards that become 1 percent more stringent each year. Readers should recognize that those year-over-year changes in stringency are *not* measured in terms of mile per gallon or CO_2 gram per mile differences (as in, 1 percent more stringent than 30 miles per gallon in one year equals 30.3 miles per gallon in the following year), but in terms of shifts in the *footprint functions* that form the basis for the *actual* CAFE and CO_2 standards (as in, on a gallon or gram per mile basis, the CAFE and CO_2 standards change by a given percentage from one model year to the next). Under some alternatives, the rate of change was the same for both passenger cars and light trucks; under others, the rate of change differed. Like the no-action alternative, all of the alternatives considered in the proposal were more stringent than the preferred alternative.

Alternatives considered in the proposal also varied in other significant ways. Alternatives 3 and 7 in the proposal involved a gradual discontinuation of CAFE and average CO_2 adjustments reflecting the use of technologies that improve air conditioner efficiency or otherwise improve fuel economy under conditions not represented by long-standing fuel economy test procedures (off-cycle adjustments, described in further detail in Section IX), although the proposal itself would have retained these flexibilities. Commenters responding to the request for comment on phasing out these flexibilities generally supported maintaining the existing program, as proposed. ~~While some commenters asked EPA to make changes to the existing program, EPA did not propose any of those changes. A separate proposed action would be a more appropriate means to consider any such changes, to allow EPA to be better informed by public comments, and EPA may consider doing so in the future.~~ Section IX contains a more thorough summary of these comments and the issues they raise, as well as the agencies' responses. Consistent with the decision to retain these flexibilities in the final rule, alternatives reflecting their phase-out have not been ~~considered~~ further analyzed in this final rule.

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EPA believes these changes should be reflected in Section 9, under the Compliance and Enforcement, where EPA would describe the off-cycle program changes which are being finalized in the SAFE rule, based on EPA's request for public comments and comments supporting certain changes.

Similar changes in following paragraphs.

Additionally, in the NPRM for this rule, EPA proposed to exclude the option for manufacturers partially to comply with tailpipe CO_2 standards by generating CO_2-equivalent emission adjustments associated with air conditioning refrigerants and leakage after MY 2020. This approach was proposed in the interest of improved harmonization between the CAFE and tailpipe CO_2 emissions programs because this optional flexibility cannot be available in the CAFE program.[155] Alternatives 1 through 8 in the proposal excluded this option. EPA requested comment "on whether to proceed with [the] proposal to discontinue accounting for A/C leakage, methane emissions, and nitrous oxide emissions as part of the CO_2 emissions standards to provide for better harmony with the CAFE program, or whether to continue to consider these factors toward compliance and retain that as a feature that differs between the programs."[156] EPA stated that if EPA were to proceed with excluding A/C refrigerant credits as proposed, "EPA would consider whether it is appropriate to initiate a new rulemaking to regulate these programs independently…."[157] EPA also stated that "[i]f the agency decides to retain the A/C leakage … provisions for CO_2 compliance, it would likely re-insert the current A/C leakage offset and increase the stringency levels for CO_2 compliance by the offset amounts described above (i.e., 13.8 g/mi equivalent for passenger cars and 17.2 g/mi equivalent for light trucks), and retain the current caps (i.e., 18.8 g/mi equivalent for passenger cars and 24.4 g/mi equivalent for light trucks).". EPA received comments from a wide range of stakeholders, most of whom opposed the elimination of these flexibility provisions.

Commented [A86]: CHANGE AS SHOWN: Changes to this footnote corrects the fact that the CAFE equation also includes hydrocarbons. Specifically, CAFE includes total hycarbons (HC), which incorporates methane.

Specifically, the two major trade organizations of auto manufacturers, as well as some individual automakers, supported retaining these provisions. Global Automakers commented that "[a]ir conditioning refrigerant leakage . . . should be included for compliance with the EPA standards for all MYs, even if it means a divergence from the NHTSA standards."[158] Global provides several detailed reasons for their comments, including that the existing provisions are "…important to maintaining regulatory flexibility through real [CO_2] emission reductions and

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[155] For the CAFE program, carbon-based tailpipe emissions (~~including~~ CO_2, HC ~~CH4~~, and CO) are measured, and fuel economy is calculated using a carbon balance equation. EPA also uses carbon-based emissions (CO_2, ~~CH4~~, HC and CO, the same as for CAFE) to calculate tailpipe CO_2 for use in determining compliance with its standards. In addition, under the no-action alternative for the proposal and under all alternatives in the final rule, in determining compliance, EPA includes~~adds on a~~ CO_2 equivalent basis (using Global Warming Potential (GWP) adjustment) ~~for~~ A/C refrigerant leakage credits, at the manufacturer's option, and nitrous oxide and methane emissions. EPA also has separate emissions standards for methane and nitrous oxides. The CAFE program does not include standards for A/C refrigerant leakage, nitrous oxide and methane emissions because they do not impact fuel economy. Under Alternatives 1-8 in the proposal, the standards were ~~completely~~ closely aligned for gasoline powered vehicles because compliance with the fleet average standards for such vehicles is based on tailpipe CO_2, HC ~~CH4~~, and CO for both programs and not emissions unrelated to fuel economy, although diesel and alternative fuel vehicles would have continued to be treated differently between the CAFE and CO_2 programs. While such an approach would have ~~significantly~~ improved harmonization between the programs, standards would not have been fully aligned because of the small fraction of the fleet that uses diesel and alternative fuels (as described in the proposal, such vehicles made up approximately four percent of the MY 2016 fleet), as well as differences involving EPCA/EISA provisions EPA has not adopted, such as minimum standards for domestic passenger cars and limits on credit transfers between regulated fleets. The proposal to eliminate flexibilities associated with A/C refrigerants and leakage was not adopted for the final rule, and the reasons for and implications of that decision are discussed further below.

[156] 83 FR at 43193 (Aug. 24, 2018).

[157] *Id.* at 43194.

[158] Global, NHTSA-2018-0067-12032, Appendix A at A-5.

would prevent the potential for additional bifurcated, separate programs at the state level."[159] The Alliance similarly commented that it "supports continuation of the full air conditioning refrigerant leakage credits under the [CO_2] standards."[160] Global and the Alliance both also expressed concerns about regulatory stability for auto manufacturers that have made investments based on existing regulations. Some individual manufacturers, including General Motors,[161] Fiat Chrysler,[162] and BMW,[163] also commented in support of maintaining the current A/C refrigerant and leakage credits.

Commented [A87]: CHANGE AS SHOWN: Since "stranded capital" was mentioned in both comments and we later cite "regulatory stability for auto manufacturers, suppliers, and refrigerant producers that have made investments based on existing regulations" as one reason for keeping the program, EPA thinks it would be helpful to say something like this here.

Auto manufacturing suppliers who addressed A/C refrigerant and leakage credits also generally supported retaining the existing provisions. MEMA commented that "It is essential for supplier investment and jobs, and continuous innovation and improvements in the technologies that the credit programs continue and expand to broaden the compliance pathways. MEMA urges the agencies to continue the current credit and incentives programs…."[164] DENSO also supported maintaining the current provisions.[165] However, BorgWarner supported the proposed

[159] *Id.* Global also stated that excluding A/C leakage credits would "…greatly limit[] the ability [of manufacturers] to select the most cost-effective approach for technology improvements and result in a costlier, separate set of regulations that actually relate to the overall [CO_2] standards." Global also expressed concern that issuing separate regulations for A/C leakage could take too long and create a gap in which States might act to separately regulate or even ban refrigerants, and supported continued inclusion of A/C leakage and refrigerant regulation in EPA's CO_2 program to avoid risk of an ensuing patchwork. Global argued that manufacturers had already invested to meet the existing program, and that "the proposed phase-out also creates another risk that manufacturers will have stranded capital in technologies that are not fully amortized." Global Automakers, EPA-HQ-OAR-2018-0283-5704, Attachment A, at A.43-44.

[160] Alliance, NHTSA-2018-0067-12073, Full Comment Set, at 12. Alliance also expressed concern about stranded capital and risk of patchwork of state regulation if MAC direct credits were not retained in the Federal CO_2 program. *Id.* at 80-81.

[161] General Motors, NHTSA-2018-0067-11858, Appendix 4, at 1 ("General Motors supports the extensive comments from the Alliance of Automobile Manufacturers regarding flexibility mechanisms, and incorporates them by reference. In particular, the Alliance cites the widening gap between the regulatory standards and actual industry-wide new vehicle average fuel economy that has become evident since 2016, despite the growing use of improvement 'credits' from various flexibility mechanisms, such as off-cycle technology credits, mobile air conditioner efficiency credits, mobile air conditioner refrigerant leak reduction credits and credits from electrified vehicles.")

[162] FCA, NHTSA-2018-0067-11943, at 8. FCA also expressed concern about patchwork in the absence of a federal rule. *Id.*

[163] BMW, EPA-HQ-OAR-2018-4204, at 3. BMW stated that "Today's rules allow flexibilities to be used by the motor vehicle manufacturers for fuel saving technologies and efficiency gains which are not covered in the applicable test procedures. To enhance the future use of these technologies and to reward motor vehicle manufacturer's investments taken for future innovations, the agencies should consider the continuation of current flexibilities for the model years 2021 to 2026."

[164] MEMA, available at https://www.mema.org/sites/default/files/resource/MEMA%20CAFE%20and%20GHG%20Vehicle%20Comments%20FINAL%20with%20Appendices%20Oct%2026%202018.pdf, comment at p. 2. MEMA also expressed concern about stranded capital investments by suppliers and supplier jobs if the direct MAC credits were not available; stated that the credits were an important compliance flexibility and "one of the highest values of any credit offered in the EPA program"; and stated that "Harmonizing the programs dores not require making them identical or equivalent. Rather, harmonization can be achieved by better coordinating the two programs to the extent feasible while allowing each agency to implement its separate and distinct mandate." *Id.* at 15-16.

[165] DENSO, NHTSA-2018-0067-11880, at 8.

removal of A/C refrigerant credits "for harmonization reasons," while encouraging EPA to regulate A/C refrigerants and leakage separately from the CO_2 standards.[166]

The two producers of a lower GWP refrigerant, Chemours and Honeywell, commented extensively in support of continuing to allow A/C refrigerant and leakage credits for CO_2 compliance, making both economic and legal arguments. Both Chemours and Honeywell stated that A/C refrigerant and leakage credits were a highly cost-effective way for OEMs to comply with the CO_2 standards,[167] with Chemours suggesting that OEM compliance strategies are based on the assumption that these credits will be available for CO_2 compliance[168] and that any increase in stringency above the proposal effectively necessitates that the credits remain part of the program.[169] Honeywell stated that all OEMs (and a variety of other parties) supported retaining the credits for CO_2 compliance,[170] and Chemours, Honeywell, and CBD *et al.* all noted that OEMs are already using the credits for low GWP refrigerants in more than 50 percent of the MY 2018 vehicles produced for sale in the U.S.[171] The American Chemistry Council also stated that the "auto industry widely supports the credits, and U.S. chemical manufacturers are at a loss as to why EPA would propose to eliminate such a successful flexible compliance program."[172] In response to NPRM statements expressing concern that the A/C refrigerant and leakage credits could be market distorting, both Chemours and Honeywell disagreed,[173] arguing that the credits were simply a highly cost-effective means of complying with the CO_2 standards,[174] and that removal of the credits at this point would, itself, distort the market for refrigerants. Honeywell argued that eliminating the A/C credit program from CO_2 compliance would put the U.S. at a competitive disadvantage with other countries, and would risk U.S. jobs.[175]

Regarding the NPRM's statements that removing the A/C refrigerant and leakage credits from CO_2 compliance would promote harmonization with the CAFE program, these commenters argued that harmonization was not a valid basis for that aspect of the proposal. Chemours, Honeywell, and CBD *et al.* all argued that Section 202(a) creates no obligation to harmonize the CO_2 program with the CAFE program.[176] Chemours further argued that to the extent disharmonization between the programs existed, it should be addressed via stringency changes

[166] BorgWarner, NHTSA-2018-0067-11895, at 10.
[167] Chemours at 1 ("MVAC credits many times offer the 'least cost' approach to compliance. . .") and 9; Honeywell at 6.
[168] Chemours at 6-7; both Chemours and Honeywell expressed concern about OEM reliance on the expectation that HFC credits would continue to be part of the CO_2 program (Chemours at 31; Honeywell at 16-20) and that investments in alternative refrigerants would be stranded (Chemours at 1, 3, 4-6; Honeywell at 2, 7-8).
[169] Chemours at 7.
[170] Honeywell at 8-11.
[171] Chemours at 4; Honeywell at 6-7; CBD *et al.* at 46-47.
[172] American Chemistry Council, EPA-HQ-OAR-2018-0283-1415, at 9-10 (comments similar to Chemours and Honeywell).
[173] Chemours at 1; Honeywell at 13.
[174] Chemours at 29-30; Honeywell at 13-14.
[175] Honeywell at 20-21.
[176] Chemours at 23-24; Honeywell at 11-12; CBD *et al.* at 47.

(i.e., reducing CAFE stringency relative to CO_2 stringency) rather than "dropping low-cost compliance options."[177]

These commenters also expressed concern that the proposal constituted an EPA decision not to regulate HFC emissions from motor vehicles at all. Commenters argued that the NPRM provided no legal analysis or reasoned explanation for stopping regulation of HFCs,[178] and that *Massachusetts v. EPA* requires any final rule to regulate all greenhouse gases from motor vehicles and not CO_2 alone,[179] suggesting that there was a high likelihood of a lapse in regulation because EPA had not yet proposed a new way of regulating HFC emissions.[180] Because the NPRM provided no specific information about how EPA might regulate non-CO_2 emissions separately, commenters argued that the lack of clarity was inherently disruptive to OEMs.[181] CBD *et al.* argued that any lapse in regulation is "illegal on its face" and that even creating a separate standard for HFC emissions would be "illegal" because it "would increase costs to manufacturers and result in environmental detriment by removing any incentive to use the most aggressive approaches to curtail emissions of these highly potent GHGs."[182]

Environmental organizations,[183] other NGOs, academic institutions, consumer organizations, and state governments[184] also commented in support of continuing the existing provisions.

EPA has considered its proposed approach to A/C refrigerant and leakage credits in light of these comments. EPA believes that maintaining this element of its program is consistent with EPA's authority under Section 202(a) to establish standards for reducing emissions from LDVs. Thus, maintaining the optional HFC credit program is appropriate. In addition, EPA recognizes the value of regulatory flexibility, ~~and~~ compliance options, and ~~of~~ regulatory stability for auto manufacturers, suppliers, and refrigerant producers that have made investments based on existing regulations, and we have concluded that we can maintain sufficient harmony between the EPA light duty GHG and NHTSA CAFE programs while retaining the existing A/C refrigerant/leakage credit program and associated offset between the GHG and CAFE standards. ~~Further, EPA has concluded that the benefits from retaining the existing A/C refrigerant leakage credit program and associated offset between the CO_2 and CAFE standards – in terms of providing for a more comprehensive regulation of emissions from light-duty vehicles – outweigh the disbenefits resulting from the lack of harmonization.~~

Commented [A88]: CHANGE AS SHOWN: EPA does not believe that NHTSA's language here is necessary under CAA 202, and it implies we have a supporting, more detailed "benefits/disbenefits" analysis, which we do not. EPA recommends we keep our previously suggested language.

Regarding the comment from BorgWarner about how having a separate A/C refrigerant and leakage regulation would allow for better harmonization between the programs, we accept

[177] Chemours at 9-11.
[178] Chemours at 1-2; Honeywell at 11.
[179] Chemours at 18-19; Honeywell at 14-16.
[180] Chemours at 6; Honeywell at 16.
[181] Chemours at 21; Honeywell at 16; ICCT at 1-39.
[182] CBD *et al.* at 46.
[183] ICCT, NHTSA-2018-0067-11741, Full Comments, at 4 (describing "air conditioning GHG-reduction technologies [as] available, cost-effective, and experiencing increased deployment by many companies due to the standards."); CBD *et al.*, Appendix A, at 45-47.
[184] CARB, NHTSA-2018-0067-11873, Detailed Comments, at 120-121; Washington State Department of Ecology, NHTSA-2018-0067-11926, at 6 (HFCs are an important GHG; compliance flexibility is important).

this to be an accurate statement, but believe the benefits of continued refrigerant regulation as described in the paragraph above, as an option for CO_2 compliance outweigh the problems associated with lack of completebenefits of full harmonization with the CAFE program.

Commented [A89]: CHANGE AS SHOWN: EPA edits in rest of this section are consistent with our comments sent to NHTSA on the Regulatory Alternatives draft section, shared on 12/2/2019.

For these reasons, EPA is not finalizing the proposed provisions, and is making no changes in the A/C refrigerant and leakage-related provisions of the current program. In light of this decisionconclusion, EPA does not need to address the legal arguments made by CBD *et al.* and CARB about how EPA might regulateing refrigerant-related emissions separately, or a potential lapses in regulation of refrigerant emissions while such a program iscould be developed.

As with A/C refrigerant and leakage credits, EPA proposed to exclude nitrous oxide and methane from average performance calculations after model year 2020, thereby removing these optional program flexibilities. Alternatives 1 through 8 excluded this option. EPA sought comment on whether to remove those aspects of the program that allow a manufacturer to use nitrous oxide and methane emissions reductions for compliance with its CO_2 average fleet standards because such a flexibility is not allowed in the NHTSA CAFE program, or whether to retain the flexibilities as a feature that differs between the programs. Further, EPA sought comment on whether to change the existing methane and nitrous oxide standards. Specifically, EPA requested information from the public on whether the existing standards are appropriate, or whether they should be revised to be less stringent or more stringent based on any updated data.

The Alliance in its comments may have misunderstood EPA's proposal to mean that EPA was proposing to eliminate regulation of methane and nitrous oxide emissions altogether. The Alliance commented in support of such a proposal as they understood it, to eliminate the standards to provide better harmony between the two compliance programs.[185] The Alliance commented that "[n]ot only is emission of these two substances from vehicles a relatively minor contribution to GHG emissions, the Alliance has continuing concern regarding measurement and testing technologies for nitrous oxide."[186] The Alliance commented further that if "EPA decides instead to continue to regulate methane and nitrous oxide, the Alliance recommends that EPA re-assess whether the levels of the standards remain appropriate and to retain the current compliance flexibilities. Furthermore, in this scenario, the Alliance also recommends that methane and nitrous oxide standards be assessed as a fleet average and as the average of FTP and HFET test cycles."[187] Several individual manufacturers submitted similar comments, including

[185] Alliance, NHTSA-2018-0067-12073, Full Comment Set, at 13.
[186] *Id.*
[187] *Id.*

Ford,[188] FCA,[189] Volvo,[190] and Mazda.[191] Ford also commented that it does not support the proposal to maintain the existing N_2O/CH_4 standards while removing the program flexibilities.[192]

The Alliance further commented that "data from the 2016 EPA report on light-duty vehicle emissions supports the position that CH_4 and N_2O have minimal impact on total GHG emissions, reporting only 0.045% in exceedance of the standard. This new information makes it apparent that CH_4 and N_2O contribute a *de minimis* amount to GHG emissions. Additionally, gasoline CH_4 and N_2O performance is within the current standards. Finally, the main producers of CH_4 and N_2O emissions are flex fuel (E85) and diesel vehicles, and these vehicles have been declining in sales as compared to gasoline-fueled vehicles."[193] The Alliance also commented that CH_4 and N_2O have minimal opportunities to be catalytically treated, as N_2O is generated in the catalyst and CH_4 has a low conversion efficiency compared to other emissions. EPA did not intend that additional hardware should be required to comply with the CH_4 or N_2O standards on any vehicle."[194]

Global Automakers commented in support of continuing inclusion of nitrous oxide and methane emissions standards for all MYs, even if it means a divergence from the NHTSA standards for these program elements in the regulations, "because they are complementary to EPA's program, and are better managed through a coordinated federal policy. They are also important to maintaining regulatory flexibility through real [CO_2] emission reductions and would prevent the potential for additional bifurcated, separate programs at the state level."[195] Global Automakers recommended that they remain in place per the existing program but continued to support that the N_2O testing is not necessary. Global Automakers commented that it "strongly recommends reducing the need for N_2O testing or eliminating these test requirements in their entirety. Global Automakers asserted that it should be sufficient to allow manufacturers to attest to compliance with the N_2O capped standards based upon good engineering judgment, development testing, and correlation to NO_X emissions, and that EPA could, however, maintain

[188] Ford, EPA-HQ-OAR-2018-0283-5691, at 4.
[189] FCA, NHTSA-2018-0067-11943, at 9.
[190] Volvo, NHTSA-2018-0067-12036, at 5.
[191] Mazda, NHTSA-2018-0067-11727, at 3 ("In reality, these emissions are at deminimis levels and have very little, if any, impact on global warming. So, the need to regulate these emissions as part of the [CO_2] program, or separately, is unclear. Although most current engines can comply with the existing requirements, there are some existing and upcoming new technologies that may not be able to fully comply. These technologies can provide substantial CO_2 reductions.")
[192] Ford, at 4 ("Finally, without the ability to incorporate exceedances into CREE, each vehicle will need to employ hardware solutions if they do not comply. We do not believe it was EPA's intent in the original rulemaking to require additional after-treatment, with associated cost increases, explicitly for the control and reduction of an insignificant contributor to GHG emissions. Therefore, we do not support the proposal to maintain the existing N_2O/CH_4 standards while removing the CREE exceedance pathway.")
[193] Alliance, NHTSA-2018-0067-12073, Full Comment Set, at 43.
[194] *Id.* at 44.
[195] Global, NHTSA-2018-0067-12032, at 4, 5.

the option to request testing to be performed for new technologies only, which could have unknown impacts on N_2O emissions."[196] Hyundai[197] and Kia[198] submitted similar comments.

Others commented in support of retaining the existing program. MECA commented that it supports the existing standards for methane and nitrous oxide because catalyst technologies provided by MECA members that reduce these climate forcing gases are readily available and cost-effective.[199] MECA also commented that the ability to trade reductions in these pollutants in exchange for CO_2 gives vehicle manufacturers the flexibilities they need to comply with the emission limits by the most cost-effective means.[200] CBD *et al.* commented that the alternative compliance mechanisms currently available in the program exist to provide cost-effective options for compliance, and were considered by manufacturers to be a necessary element of the program for certain types of vehicles.[201] CBD *et al.* further argued that "[e]liminating these flexibilities consequently imposes costs on manufacturers without discernible environmental benefits," and suggested that harmonization with the CAFE program was not a relevant decision factor for EPA.[202] Several other parties commented generally in support of retaining the existing program for A/C leakage credits, discussed above, and N_2O and CH_4 standards.[203]

After considering these comments, EPA is retaining the regulatory provisions related to the N_2O and CH_4 standards with no changes, specifically including the existing flexibilities that accompany those standards. EPA is not adopting its proposal to exclude nitrous oxide and methane emissions from average performance calculations after model year 2020 or any other changes to the program. The standards continue to serve their intended purpose of capping emissions of those pollutants and providing for more-comprehensive regulation of emissions from light-duty vehicles. The standards were intended to prevent future emissions increases, and these standards were generally not expected to result in the application of new technologies or significant costs for manufacturers using current vehicle designs.[204] The program flexibilities are working as intended and all manufacturers are successfully complying with the standards. Most vehicle models are well below the standards and for those that are above the standards, manufacturers have used the flexibilities to offset exceedances with CO_2 improvements to demonstrate compliance. EPA did not receive any data in response to its request for comments supporting potential alternative levels of stringency.

While the Alliance and several individual manufacturers recommended eliminating the standards altogether, EPA did not propose to eliminate the standards, but rather to eliminate the optional flexibilities, and solicited comment on adjusting the standards to be more or less stringent. Thus, EPA does not believe it would be appropriate to eliminate ~~completely~~ the

[196] Global, Appendix A, NHTSA-2018-0067-12032, at A-44, fn. 89.
[197] Hyundai, EPA-HQ-OAR-2018-0283-4411, at 7.
[198] Kia, EPA-HQ-OAR-2018-0283-4195, at 8-9.
[199] MECA, NHTSA-2018-0067-11994, at 12.
[200] *Id.*
[201] CBD *et al.* at 48.
[202] *Id.*
[203] Washington State Department of Ecology, NHTSA-2018-0067-11926, at 6.
[204] 77 FR 62624, at 62799 (Oct 15, 2012).

standards in this final rule without providing an opportunity for comment on that idea. Furthermore, as noted above, EPA believes the standards are continuing to serve their intended purpose of capping emissions and remain appropriate. Manufacturers have been subject to the standards for several years, and the Alliance acknowledges in their comments that the exceedance of the standards, which is offset by manufacturers using compliance flexibilities, is very small and that most vehicles meet the standards. Regarding the Alliance comments that the standards should be based on a fleet average approach, EPA notes that the purpose of the standards is to cap emissions, not to achieve fleet-wide reductions.[205] The fleet average emissions for N_2O and CH_4 are well below the numerical level of the cap standards and therefore the existing cap standards would not be an appropriate fleet average standard. Adopting a fleet average approach using the same numerical level as the established cap standards would allow the opportunity for backsliding and would not achieve the intended goal of capping emissions at current levels. If technologies lead to exceedances of the caps, automakers have the opportunity to apply appropriate flexibilities under the current program to achieve GHG emission neutrality. EPA is not aware of any manufacturer that has been prevented from bringing a technology to the marketplace because of the current cap levels or approach. EPA believes it would need to consider all options further, with an opportunity for public comment, before adopting such a significant change to the program.

As explained above, the agencies have changed the alternatives considered for the final rule, partly in response to comments. The basic form of the standards represented by the alternatives – footprint-based, defined by particular mathematical functions – remains the same and as described in the NPRM. For the EPA program, EPA has chosen in this final rule to retain the existing program for regulation of A/C refrigerant leakage, nitrous oxide, and methane emissions as part of the CO_2 standard. This allows manufacturers to continue to rely on this flexibility which they describe as extremely important for compliance, although it results in continued differences between EPA's and NHTSA's programs. This approach also avoids the possibility of gaps in the regulation of HFCs, CH_4, and N_2O while EPA developed a different way of regulating the non-CO_2 emissions as part of or concurrent with the NPRM, and thereby allows EPA to continue to regulate GHG emissions from light-duty vehicles on a more comprehensive basis. Thus, all alternatives considered in this final rule reflect inclusion of CH_4, N_2O, and HFC in EPA's overall "CO_2" (more accurately, CO_2-equivalent, or CO_2e) requirements. Besides this provisionchange, the alternatives considered for the final rule differ from the NPRM in two additional ways: first, alternatives reflecting the phase-out of the A/C efficiency and off-cycle programs have been dropped in response to certain comments received and in recognition of the potential real-world benefits of those programs. And second, the preferred alternative for this final standardsrule reflects a 1.5 percent year-over-year stringency increase for both passenger cars and light trucks. These changes will be discussed further below, following a brief discussion of the form of the standards.

Commented [A90]: CHANGE AS SHOWN: As commented above, EPA sees no need to defend or further discuss hypothetically removing the HFCs, CH_4, and N_2O credit provisions since we are not finalizing the removal.

[205] Relatedly, the Alliance and Global Automakers raised concerns in their comments regarding N_2O measurement and testing burden. EPA did not propose any changes in testing requirements and at this time EPA is not adopting any changes. Manufacturers have been measuring N_2O emissions and have successfully certified vehicles to the N_2O standards for several years and EPA does not believe N_2O measurement is an issue needing regulatory change. EPA continues to believe direct measurement is the best way for manufacturers to demonstrate compliance with the N_2O stanards and is more appropriate than an engineering statement without direct measurement.

A. Form of the standards

As in the CAFE and CO_2 rulemakings in 2010 and 2012, NHTSA and EPA proposed in the NPRM to set attribute-based CAFE and CO_2 standards defined by a mathematical function of vehicle footprint, which has observable correlation with fuel economy and vehicle emissions. EPCA, as amended by EISA, expressly requires that CAFE standards for passenger cars and light trucks be based on one or more vehicle attributes related to fuel economy and be expressed in the form of a mathematical function.[206] While the CAA includes no specific requirements regarding the form of GHG regulation standards, EPA has chosen to adopt attribute-based CO_2 standards consistent with NHTSA's EPCA/EISA requirements in the interest of harmonization and simplifying compliance. Such an approach is permissible under section 202(a) of the CAA, and EPA has used the attribute-based approach in issuing standards under analogous provisions of the CAA. Thus, both the proposed and final standards take the form of fuel economy and CO_2 targets expressed as functions of vehicle footprint (the product of vehicle wheelbase and average track width). Section V.A.2 below discusses the agencies' continued reliance on footprint as the relevant attribute.

Under the footprint-based standards, the function defines a CO_2 or fuel economy performance target for each unique footprint combination within a car or truck model type. Using the functions, each manufacturer thus will have a CAFE and CO_2 average standard for each year that is almost certainly unique to each of its fleets,[207] based upon the footprints and production volumes of the vehicle models produced by that manufacturer. A manufacturer will have separate footprint-based standards for cars and for trucks. The functions are mostly sloped, so that generally, larger vehicles (i.e., vehicles with larger footprints) will be subject to lower CAFE mpg targets and higher CO_2 grams/mile targets than smaller vehicles. This is because, generally speaking, smaller vehicles are more capable of achieving higher levels of fuel economy/lower levels of CO_2 emissions, mostly because they tend not to have to work as hard (and therefore require as much energy) to perform their driving task. Although a manufacturer's fleet average standards could be estimated throughout the model year based on the projected production volume of its vehicle fleet (and are estimated as part of EPA's certification process), the standards to which the manufacturer must comply are determined by its final model year production figures. A manufacturer's calculation of its fleet average standards as well as its fleets' average performance at the end of the model year will thus be based on the production-weighted average target and performance of each model in its fleet.[208]

For passenger cars, consistent with prior rulemakings, NHTSA is defining fuel economy targets as follows:

[206] 49 U.S.C. 32902(a)(3)(A).

[207] EPCA/EISA requires NHTSA to separate passenger cars into domestic and import passenger car fleets whereas EPA combines all passenger cars into one fleet.

[208] As discussed in prior rulemakings, a manufacturer may have some vehicle models that exceed their target and some that are below their target. Compliance with a fleet average standard is determined by comparing the fleet average standard (based on the production-weighted average of the target levels for each model) with fleet average performance (based on the production-weighted average of the performance of each model).

$$TARGET_{FE} = \frac{1}{MIN\left[MAX\left(c \times FOOTPRINT + d, \frac{1}{a}\right), \frac{1}{b}\right]}$$

where

$TARGET_{FE}$ is the fuel economy target (in mpg) applicable to a specific vehicle model type with a unique footprint combination,

a is a minimum fuel economy target (in mpg),

b is a maximum fuel economy target (in mpg),

c is the slope (in gallons per mile per square foot, or gpm, per square foot) of a line relating fuel consumption (the inverse of fuel economy) to footprint, and

d is an intercept (in gpm) of the same line.

Here, *MIN* and *MAX* are functions that take the minimum and maximum values, respectively, of the set of included values. For example, *MIN*[40,35] = 35 and *MAX*(40, 25) = 40, such that *MIN*[*MAX*(40, 25), 35] = 35.

For light trucks, also consistent with prior rulemakings, NHTSA is defining fuel economy targets as follows:

$$TARGET_{FE} = MAX\left(\frac{1}{MIN\left[MAX\left(c \times FOOTPRINT + d, \frac{1}{a}\right), \frac{1}{b}\right]}, \frac{1}{MIN\left[MAX\left(g \times FOOTPRINT + h, \frac{1}{e}\right), \frac{1}{f}\right]}\right)$$

where

$TARGET_{FE}$ is the fuel economy target (in mpg) applicable to a specific vehicle model type with a unique footprint combination,

a, b, c, and d are as for passenger cars, but taking values specific to light trucks,

e is a second minimum fuel economy target (in mpg),

f is a second maximum fuel economy target (in mpg),

g is the slope (in gpm per square foot) of a second line relating fuel consumption (the inverse of fuel economy) to footprint, and

h is an intercept (in gpm) of the same second line.

Although the general model of the target function equation is the same for each vehicle category (passenger cars and light trucks) and each model year, the parameters of the function equation differ for cars and trucks. For MYs 2020-2026, the parameters are unchanged, resulting in the same stringency in each of those model years.

Mathematical functions defining the CO_2 targets are expressed as functions that are similar, with coefficients *a-h* corresponding to those listed above.[209] For passenger cars, EPA is defining CO_2 targets mathematically equivalent to the following:

$$TARGET_{CO2} = MIN[b, MAX[a, c \times FOOTPRINT + d]]$$

where

$TARGET_{CO2}$ is the is the CO_2 target (in grams per mile, or g/mi) applicable to a specific vehicle model configuration,

a is a minimum CO_2 target (in g/mi),

b is a maximum CO_2 target (in g/mi),

c is the slope (in g/mi, per square foot) of a line relating CO_2 emissions to footprint, and

d is an intercept (in g/mi) of the same line.

For light trucks, CO_2 targets are defined as follows:

$$TARGET_{CO2} = MIN[MIN[b, MAX[a, c \times FOOTPRINT + d]], MIN[f, MAX[e, g \times FOOTPRINT + h]]]$$

where

$TARGET_{CO2}$ is the is the CO_2 target (in g/mi) applicable to a specific vehicle model configuration,

a, *b*, *c*, and *d* are as for passenger cars, but taking values specific to light trucks,

e is a second minimum CO_2 target (in g/mi),

f is a second maximum CO_2 target (in g/mi),

g is the slope (in g/mi per square foot) of a second line relating CO_2 emissions to footprint, and

[209] EPA regulations use a different but mathematically equivalent approach to specify targets. Rather than using a function with nested minima and maxima functions, EPA regulations specify requirements separately for different ranges of vehicle footprint. Because these ranges reflect the combined application of the listed minima, maxima, and linear functions, it is mathematically equivalent and more efficient to present the targets as in this Section.

h is an intercept (in g/mi) of the same second line.

To be clear, as has been the case since the agencies began establishing attribute-based standards, no vehicle need meet the specific applicable fuel economy or CO_2 targets, because compliance with either CAFE or CO_2 standards is determined based on corporate average fuel economy or fleet average CO_2 emission rates. In this respect, CAFE and CO_2 standards are unlike, for example, safety standards ~~and traditional vehicle emissions standards~~. CAFE and CO_2 standards apply to the average fuel economy levels and CO_2 emission rates achieved by manufacturers' entire fleets of vehicles produced for sale in the U.S. Safety standards apply on a vehicle-by-vehicle basis, such that every single vehicle produced for sale in the U.S. must, on its own, comply with minimum FMVSS. ~~Similarly, criteria pollutant emissions standards are applied on a per-vehicle basis, such that every vehicle produced for sale in the U.S. must, on its own, comply with all applicable emissions standards.~~ When first mandating CAFE standards in the 1970s, Congress specified a more flexible averaging-based approach that allows some vehicles to "under comply" (i.e., fall short of the overall flat standard, or fall short of their target under attribute-based standards) as long as a manufacturer's overall fleet is in compliance.

Commented [A91]: CHANGE AS SHOWN: EPA's light-duty CAA emission standards for several pollutants are and have been in the past fleet-wide averages (e.g., Tier 2 and Tier 3 standards).

The required CAFE level applicable to a given fleet in a given model year is determined by calculating the production-weighted harmonic average of fuel economy targets applicable to specific vehicle model configurations in the fleet, as follows:

$$CAFE_{required} = \frac{\sum_i PRODUCTION_i}{\sum_i \frac{PRODUCTION_i}{TARGET_{FE,i}}}$$

where

$CAFE_{required}$ is the CAFE level the fleet is required to achieve,

i refers to specific vehicle model/configurations in the fleet,

$PRODUCTION_i$ is the number of model configuration *i* produced for sale in the U.S., and

$TARGET_{FE,i}$ the fuel economy target (as defined above) for model configuration *i*.

Similarly, the required average CO_2 level applicable to a given fleet in a given model year is determined by calculating the production-weighted average (not harmonic) of CO_2 targets applicable to specific vehicle model configurations in the fleet, as follows:

$$CO2_{required} = \frac{\sum_i PRODUCTION_i \times TARGET_{CO2,i}}{\sum_i PRODUCTION_i}$$

where

$CO2_{required}$ is the average CO_2 level the fleet is required to achieve,

i refers to specific vehicle model/configurations in the fleet,

PRODUCTION$_i$ is the number of model configuration *i* produced for sale in the U.S., and

TARGET$_{CO2,i}$ is the CO_2 target (as defined above) for model configuration *i*.

Section V.A.1 describes the advantages of attribute standards, generally. Section V.A.2 explains the agencies' specific decision to use vehicle footprint as the attribute over which to vary stringency for past and current rules. Section V.A.3 discusses the policy considerations in selecting the specific mathematical function. Section V.A.4 discusses the methodologies used to develop current attribute-based standards, and the agencies' current proposal to continue to do so for MYs 2022-2026. Section V.A.5 discusses the methodologies used to reconsider the mathematical function for the proposed standards.

1. Why Attribute-Based Standards, and what are the Benefits?

Under attribute-based standards, every vehicle model has fuel economy and CO_2 targets, the levels of which depend on the level of that vehicle's determining attribute (for the MYs 2021-2026 standards, footprint is the determining attribute, as discussed below). The manufacturer's fleet average CAFE performance is calculated by the harmonic production-weighted average of those targets, as defined below:

$$Required\ CAFE = \frac{\sum_{i \in OEM\ Fleet} Production_i}{\sum_{i \in OEM\ Fleet} \frac{Production_i}{Target_i}}$$

Here, *i* represents a given model[210] in a manufacturer's fleet, *Production*$_i$ represents the U.S. production of that model, and *Target*$_i$ represents the target as defined by the attribute-based standards. This means no vehicle is required to meet its target; instead, manufacturers are free to balance improvements however they deem best within (and, given credit transfers, at least partially across) their fleets.

Because CO_2 is on a gram per mile basis rather a mile per gallon basis, harmonic averaging is not necessary when calculating required CO_2 levels:

$$Required\ CO_2 = \frac{\sum_{i \in OEM\ Fleet} Production_i \times Target_i}{\sum_{i \in OEM\ Fleet} Production_i}$$

The idea is to select the shape of the mathematical function relating the standard to the fuel economy-related attribute to reflect the trade-offs manufacturers face in producing more of that attribute over fuel efficiency (due to technological limits of production and relative demand of each attribute). If the shape captures these trade-offs, every manufacturer is more likely to

[210] If a model has more than one footprint variant, here each of those variants is treated as a unique model, *i*, since each footprint variant will have a unique target.

continue adding fuel-efficient technology across the distribution of the attribute within their fleet, instead of potentially changing the attribute — and other correlated attributes, including fuel economy — as a part of their compliance strategy. Attribute-based standards that achieve this have several advantages.

First, assuming the attribute is a measurement of vehicle size, attribute-based standards help to at least partially reduce the incentive for manufacturers to respond to CAFE and CO_2 standards by reducing vehicle size in ways harmful to safety, as compared to "flat," non-attribute based standards.[211] Larger vehicles, in terms of mass and/or crush space, generally consume more fuel and produce more carbon dioxide emissions, but are also generally better able to protect occupants in a crash.[212] Because each vehicle model has its own target (determined by a size-related attribute), properly fitted attribute-based standards reduce the incentive to build smaller vehicles simply to meet a fleet-wide average, because smaller vehicles are subject to more stringent compliance targets.

Second, attribute-based standards, if properly fitted, provide automakers with more flexibility to respond to consumer preferences than do single-valued standards. As discussed above, a single-valued standard encourages a fleet mix with a larger share of smaller vehicles by creating incentives for manufacturers to use downsizing the average vehicle in their fleet (possibly through fleet mixing) as a compliance strategy, which may result in manufacturers building vehicles for compliance reasons that consumers do not want. Under a size-related, attribute-based standard, reducing the size of the vehicle for compliance's sake is a less-viable strategy because smaller vehicles have more stringent regulatory targets. As a result, the fleet mix under such standards is more likely to reflect aggregate consumer demand for the size-related attribute used to determine vehicle targets.

Third, attribute-based standards provide a more equitable regulatory framework across heterogeneous manufacturers who may each produce different shares of vehicles along attributes correlated with fuel economy.[213] An industry-wide single-value CAFE standard imposes disproportionate cost burden and compliance challenges on manufacturers who produce more vehicles with attributes inherently correlated with lower fuel economy — i.e. manufacturers who produce, on average, larger vehicles. As discussed above, retaining flexibility for manufacturers to produce vehicles which respect heterogeneous market preferences is an important consideration. Since manufacturers may target different markets as a part of their business

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[211] The 2002 NAS Report described at length and quantified the potential safety problem with average fuel economy standards that specify a single numerical requirement for the entire industry. *See* Transportation Research Board and National Research Council. 2002. *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*, Washington, DC: The National Academies Press ("2002 NAS Report") at 5, finding 12, *available at* https://www.nap.edu/catalog/10172/effectiveness-and-impact-of-corporate-average-fuel-economy-cafe-standards (last accessed June 15, 2018). Ensuing analyses, including by NHTSA, support the fundamental conclusion that standards structured to minimize incentives to downsize all but the largest vehicles will tend to produce better safety outcomes than flat standards.

[212] Bento, A., Gillingham, K., & Roth, K. (2017). The Effect of Fuel Economy Standards on Vehicle Weight Dispersion and Accident Fatalities. NBER Working Paper No. 23340. *Available at* http://www.nber.org/papers/w23340 (last accessed June 15, 2018).

[213] 2002 NAS Report at 4-5, finding 10.

strategy, ensuring that these manufacturers do not incur a disproportionate share of the regulatory cost burden is an important part of conserving consumer choices within the market.

Industry commenters generally supported attribute-based standards, while other commenters questioned their benefits. IPI argued that preserving the current vehicle mix was not necessarily desirable or necessary for consumer welfare, and suggested that some vehicle downsizing in the fleet might be beneficial both for safety and for compliance.[214] IPI also argued that compliance credit trading would "help smooth out any disproportionate impacts on certain manufacturers" and "ensure that manufacturers with relatively efficient fleets still have an incentive to continue improving fuel economy (in order to generate credits)"[215] Similarly, citing Ito and Sallee, Kathryn Doolittle commented that "…Ito and Sallee (2018) have found ABR ["attribute-based regulations"] inefficient in cost when juxtaposed with flat standard with compliance trading."[216]

The agencies have considered these comments. IPI incorrectly characterizes the agencies' prior statements as claims that it is important to preserve the current vehicle mix. EPA and NHTSA have never claimed, and are not today claiming that it is important to preserve the current fleet mix. We have said, and are today reiterating, that it is reasonable to expect that reducing the tendency of standards to ~~distort the market~~shift market share should reduce at least part of the tendency of standards to reduce consumer welfare. ~~Or, more concisely, it's better to work with the market than against it.~~ Single-value (aka flat) CAFE standards ~~in place from the 1970s through 2010 were clearly distortionary~~likely had an influence on the size and vehicle weight in the 1970's and 1980's. Recognizing this, the National Academy of Sciences recommended in 2002 that NHTSA adopt attribute-based CAFE standards. NHTSA *did so in* 2006, for light trucks produced starting MY 2008. As mentioned above, in 2007, Congress codified the requirement for attribute-based passenger car and light truck CAFE standards. Agreeing with this history, premise, and motivation, EPA has also adopted attribute-based CO_2 standards. None of this is to say the agencies consider it important to hold fleet mix constant. Rather, the agencies expect that, compared to flat standards, attribute-based standards can allow the market—including fleet mix—to better follow its natural course, and all else equal, consumer acceptance is likely to be greater if the market does so.

Commented [A92]: CHANGE AS SHOWN: This is not necessarily the case. One of the modeled consequences of the Augural standards is to increase the share of trucks and vehicles with larger footprints. (e.g. consumers who wouldn't choose a 20mpg CUV over a car, but would choose a 30mpg CUV). Assuming that consumers gain welfare from larger vehicles, this is a case where shifting the market may increase consumer welfare.

EPA suggests replacing the terms "distort" and "reduce" with directionally-neutral language.

The agencies also disagree with comments implying that compliance credit trading can address all of the market distortion that flat standards would entail. Evidence thus far suggests that trading is fragmented, with some manufacturers apparently willing to trade only with some other specific manufacturers. The Ito and Sallee article cited by one commenter is a highly idealized theoretical construction, with the authors noting, *inter alia*, that their model "assumes perfect competition."[217] Its findings regarding comparative economic efficiency of flat- and

[214] IPI, NHTSA-2018-0067-12362, at 14-15.
[215] IPI, NHTSA-2018-0067-12362, at 14.
[216] Doolittle, K, NHTSA-2018-0067-7411. See also Ito, K and Sallee, J. "The Economics of Attribute-Based Regulation: Theory and Evidence from Fuel Economy Standards". *The Review of Economics and Statistics*. 2018; 100(2); 319-336.
[217] Ito and Sallee, *op. cit.*, Supplemental Appendix, at A-15, available at https://www.mitpressjournals.org/doi/suppl/10.1162/REST_a_00704/suppl_file/REST_a_00704-esupp.pdf (accessed October 29, 2019).

attribute-based standards are, therefore, merely hypothetical, and the agencies find little basis in recent transactions to suggest the compliance credit trading market reflects the authors' idealized assumptions. Even if the agencies did expect credit trading markets to operate as in an idealized textbook example, basing the structure of standards on the presumption of perfect trading would not be appropriate. FCA commented that "…when flexibilities are considered while setting targets, they cease to be flexibilities and become simply additional technology mandates," and the Alliance commented, similarly, that "the Agencies should keep 'flexibilities' as optional ways to comply and not unduly assume that each flexibility allows additional stringency of footprint-based standards."[218] Perhaps recognizing this reality, Congress has barred NHTSA from considering manufacturers' ability to use compliance credits (even credits earned and used by the same OEM, much less credits traded between OEMs). As discussed further in section VIII.A.2.(e), EPA believes that while credit trading may be a useful flexibility to reduce the overall costs of the program, it is important to set standards in a way that does not rely on credit purchasing availability as a compliance mechanism. ~~EPA agrees that it would not be appropriate or reasonable to base the structure of its standard on the presumption that, for example, FCA could satisfy its buyers by continuing to underwrite Tesla purchases (for which, moreover, EPA is setting aside emissions from electricity generation).~~

Commented [A93]: CHANGE AS SHOWN: EPA does not agree that this characterization is appropriate, and believes that the above response to these comments is sufficient. EPA does under the CAA have the ability to consider emissions trading between firms when setting standards (and we have done so for other CAA Title II standards), and we do not want this statement to be a basis for litigation on this rule or restrict EPA's future consideration of this authority.

In addition, in this Final Rule EPA is maintaining the approach we have had with all previous EPA standards for vehicles of holding the vehicle manufacturers responsible for the vehicle emissions (the tailpipe emissions), thus we are not "setting aside" those emissions, any more then we are setting aside the differential upstream emissions that come from differences in any fuels (e.g., gasoline as compared to diesel as compared to natural gas, etc.)

Considering these comments and realities, considering EPCA's requirement for attribute-based CAFE standards, and considering the benefits of regulatory harmonization, the agencies are, again, finalizing attribute-based CAFE and CO_2 standards rather than, for either program, finalizing flat standards.

2. Why Footprint as the Attribute?

It is important that the CAFE and CO_2 standards be set in a way that does not unnecessarily incentivize manufacturers to respond by selling vehicles that are less safe. Vehicle size is highly correlated with vehicle safety for this reason, it is important to choose an attribute correlated with vehicle size (mass or some dimensional measure). Given this consideration, there are several policy and technical reasons why footprint is considered to be the most appropriate attribute upon which to base the standards, even though other vehicle size attributes (notably, curb weight) are more strongly correlated with fuel economy and tailpipe CO_2 emissions.

First, mass is strongly correlated with fuel economy; it takes a certain amount of energy to move a certain amount of mass. Footprint has some positive correlation with frontal surface area, likely a negative correlation with aerodynamics, and therefore fuel economy, but the relationship is less deterministic. Mass and crush space (correlated with footprint) are both important safety considerations. As discussed below and in the accompanying PRIA, NHTSA's research of historical crash data indicates that holding footprint constant, and decreasing the mass of the largest vehicles, will result in a net positive safety impact to drivers overall, while holding footprint constant and decreasing the mass of the smallest vehicles will result in a net decrease in fleetwide safety. Properly fitted footprint-based standards provide little, if any,

[218] FCA, NHTSA-2018-0067-11943, at 6; Alliance, NHTSA-2018-0067-12073, Full Comment Set, at 40, fn. 82

incentive to build smaller footprint vehicles to meet CAFE and CO_2 standards, and therefore help minimize the impact of standards on overall fleet safety.

Second, it is important that the attribute not be easily manipulated in a manner that does not achieve the goals of EPCA or other goals, such as safety. Although weight is more strongly correlated with fuel economy than footprint, there is less risk of artificial manipulation (i.e., changing the attribute(s) to achieve a more favorable target) by increasing footprint under footprint-based standards than there would be by increasing vehicle mass under weight-based standards. It is relatively easy for a manufacturer to add enough weight to a vehicle to decrease its applicable fuel economy target a significant amount, as compared to increasing vehicle footprint, which is a much more complicated change that typically takes place only with a vehicle redesign.

Further, some commenters on the MY 2011 CAFE rulemaking were concerned that there would be greater potential for such manipulation under multi-attribute standards, such as those that also depend on weight, torque, power, towing capability, and/or off-road capability. As discussed in NHTSA's MY 2011 CAFE final rule,[219] it is anticipated that the possibility of manipulation is lowest with footprint-based standards, as opposed to weight-based or multi-attribute-based standards. Specifically, standards that incorporate weight, torque, power, towing capability, and/or off-road capability in addition to footprint would not only be more complex, but by providing degrees of freedom with respect to more easily adjusted attributes, they could make it less certain that the future fleet would actually achieve the projected average fuel economy and CO_2 levels. This is not to say that a footprint-based system eliminates manipulation, or that a footprint-based system eliminates the possibility that manufacturers will change vehicles in ways that compromise occupant protection, but footprint-based standards achieve the best balance among affected considerations.

Several stakeholders commented on whether vehicular footprint is the most suitable attribute upon which to base standards. IPI commented that "... footprint-based standards may be unnecessary to respect consumer preferences, may negatively impact safety, and may be overall inefficient. Several arguments call into question the footprint-based approach, but a particularly important one is that large vehicles can impose a negative safety externality on other drivers."[220] IPI commented, further, that the agencies should consider the relative merits of other vehicle attributes, including vehicle fuel type, suggesting that it would be more difficult for manufacturers to manipulate a flatter standard or one "differentiated by fuel type."[221] Similarly, Michalek and Whitefoot recommended "that the agencies reexamine automaker response to the footprint-based standards to determine if adjustments should be made to avoid inducing increases to vehicle size."[222]

Conversely, ICCT commented that "the switch to footprint-based CAFE and [CO_2] standards has been widely credited with diminishing safety concerns with efficiency standards.

[219] *See* 74 FR at 14359 (Mar. 30, 2009).
[220] IPI, NHTSA-2018-0067-12362, at 12.
[221] IPI, NHTSA-2018-0067-12362, at 13 *et seq.*
[222] Michalek, J. and Whitefoot, K., NHTSA-2018-0067-11903, at 13.

Footprint standards encourage larger vehicles with wider track width, which reduces rollovers, and longer wheelbase, which increases the crush space and reduces deceleration forces for both vehicles in a two-vehicle collision."[223] Similarly, BorgWarner commented that "the use of a footprint standard not only provides greater incentive for mass reduction, but also encourages a larger footprint for a given vehicle mass, thus providing increased safety for a given mass vehicle,"[224] and the Aluminum Association commented footprint based standards drive "fuel-efficiency improvement across all vehicle classes," "eliminate the incentive to shift fleet volume to smaller cars which has been shown to slightly decrease safety in vehicle-to-vehicle collisions," and provide "an incentive for reducing weight in the larger vehicles, where weight reduction is of the most benefit for societal safety," citing Ford's aluminum-intensive F150 pickup truck as an example.[225] NADA urged the agencies to continue basing standards on vehicle footprint, as doing so "serves both to require and allow OEMs to build more fuel-efficient vehicles across the broadest possible light-duty passenger car and truck spectrum,"[226] and UCS commented that footprint-based standards "increase consumer choice, ensuring that the vehicles available for purchase in every vehicle class continue to get more efficient."[227] Furthermore, regarding concerns that footprint-based standards may be susceptible to manipulation, the Alliance commented that "the data above [from Novation Analytics] shows there are no systemic footprint increases (or any type of target manipulation) occurring."[228] While FCA's comments supported this Alliance comment, FCA commented further that, lacking some utility-related vehicle attributes such as towing capability, 4-wheel-drive, and ride height, "it is clear the footprint standard does not fully account for pickup truck capability and the components needed such as larger powertrains, greater mass and frontal area," and requested the agencies "correct LDT standards to reflect the current market preference for capability over efficiency, and introduce mechanisms into the regulation that can adjust for efficiency and capability tradeoffs that footprint standards currently ignore."[229]

When first electing to adopt footprint-based standards, NHTSA carefully considered other alternatives, including vehicle mass and "shadow" (overall width multiplied by overall length). Compared to both of these other alternatives, footprint is much less susceptible to gaming, because while there is some potential to adjust track width, wheelbase is more expensive to change, at least outside a planned vehicle redesign. EPA agreed with NHTSA's assessment, nothing has changed the relative merits of at least these three potential attributes, and nothing in the evolution of the fleet demonstrates that footprint-based standards are leading manufacturers to increase the footprint of specific vehicle models by more than they would in response to customer demand. Also, even if footprint-based standards are encouraging some increases in vehicle size, NHTSA continues to maintain, and EPA to agree, that such increases should tend to improve overall highway safety rather than degrading it. Regarding FCA's request that the agencies adopt an approach that accounts for a wider range of vehicle attributes related to both vehicle fuel economy and customer-facing vehicle utility, the agencies are concerned that doing

[223] ICCT, NHTSA-2018-0067-11741, at B-4.
[224] BorgWarner, NHTSA-2018-0067-11893, at 10.
[225] Aluminum Association, NHTSA-2018-0067-11952, at 3.
[226] NADA, NHTSA-2018-0067-12064, at 13.
[227] UCS, UCS, NHTSA-2018-0067-12039, at 46.
[228] Alliance, NHTSA-2018-0067-12073, at 123.
[229] FCA, NHTSA-2018-0067-11943, at 49.

so could further complicate already-complex standards and also lead to unintended consequences. For example, it is not currently clear how a multi-attribute approach would appropriately balance emphasis between vehicle attributes (e.g., how much relative fuel consumption should be attributed to, respectively, vehicle footprint, towing capacity, drive type, and ground clearance). Also, basing standards on, in part, ground clearance would encourage manufacturers to increase ride height, potentially increasing the frequency of vehicle rollover crashes. Regarding IPI's recommendation that fuel type be included as a vehicle attribute for attribute-based standards, the agencies note that both CAFE and CO_2 standards already account for fuel type in the procedures for measuring fuel economy levels and CO_2 emission rates, and for calculating fleet average CAFE and CO_2 levels.

Therefore, having considered public comments on the choice of vehicle attributes for CAFE and CO_2 standards, the agencies are finalizing standards that, as proposed, are defined in terms of vehicle footprint.

3. What mathematical function should be used to specify footprint-based standards?

In requiring NHTSA to "prescribe by regulation separate average fuel economy standards for passenger and non-passenger automobiles based on 1 or more vehicle attributes related to fuel economy and express each standard in the form of a mathematical function", EPCA/EISA provides ample discretion regarding not only the selection of the attribute(s), but also regarding the nature of the function. The CAA provides no specific direction regarding the form of CO_2 standards/regulation, and EPA has continued to harmonize this aspect of its CO_2 regulations with NHTSA's CAFE regulations. The relationship between fuel economy (and CO_2 emissions) and footprint, though directionally clear (*i.e.*, fuel economy tends to decrease and CO_2 emissions tend to increase with increasing footprint), is theoretically vague, and quantitatively uncertain; in other words, not so precise as to *a priori* yield only a single possible curve.

The decision of how to specify this mathematical function therefore reflects some amount of judgment. The function can be specified with a view toward achieving different environmental and petroleum reduction goals, encouraging different levels of application of fuel-saving technologies, avoiding any adverse effects on overall highway safety, reducing disparities of manufacturers' compliance burdens, and preserving consumer choice, among other aims. The following are among the specific technical concerns and resultant policy tradeoffs the agencies have considered in selecting the details of specific past and future curve shapes:

- Flatter standards (i.e., curves) increase the risk that both the size of vehicles will be reduced, potentially compromising highway safety, and reducing any utility consumers would have gained from a larger vehicle.
- Steeper footprint-based standards may create incentives to upsize vehicles, potentially oversupplying vehicles of certain footprints beyond what consumers would naturally demand, and thus increasing the possibility that fuel savings and CO_2 reduction benefits will be forfeited artificially.

- Given the same industry-wide average required fuel economy or CO_2 standard, flatter standards tend to place greater compliance burdens on full-line manufacturers.
- Given the same industry-wide average required fuel economy or CO_2 standard, dramatically steeper standards tend to place greater compliance burdens on limited-line manufacturers (depending of course, on which vehicles are being produced).
- If cutpoints are adopted, given the same industry-wide average required fuel economy, moving small-vehicle cutpoints to the left (*i.e.*, up in terms of fuel economy, down in terms of CO_2 emissions) discourages the introduction of small vehicles, and reduces the incentive to downsize small vehicles in ways that could compromise overall highway safety.
- If cutpoints are adopted, given the same industry-wide average required fuel economy, moving large-vehicle cutpoints to the right (*i.e.*, down in terms of fuel economy, up in terms of CO_2 emissions) better accommodates the design requirements of larger vehicles — especially large pickups — and extends the size range over which downsizing is discouraged.

4. What mathematical functions have been used previously, and why?

Notwithstanding the aforementioned discretion under EPCA/EISA, data should inform consideration of potential mathematical functions, but how relevant data is defined and interpreted, and the choice of methodology for fitting a curve to that data, can and should include some consideration of specific policy goals. This section summarizes the methodologies and policy concerns that were considered in developing previous target curves (for a complete discussion see the 2012 FRIA).

As discussed below, the MY 2011 final curves followed a constrained logistic function defined specifically in the final rule.[230] The MYs 2012-2021 final standards and the MYs 2022-2025 augural standards are defined by constrained linear target functions of footprint, as shown below:[231]

$$Target = \frac{1}{\min\left(\max\left(c * Footprint + d, \frac{1}{a}\right), \frac{1}{b}\right)}$$

Here, *Target* is the fuel economy target applicable to vehicles of a given footprint in square feet (*Footprint*). The upper asymptote, a, and the lower asymptote, b, are specified in mpg; the reciprocal of these values represent the lower and upper asymptotes, respectively, when

[230] *See* 74 Fed. Reg. 14196, 14363-14370 (Mar. 30, 2009) for NHTSA discussion of curve fitting in the MY 2011 CAFE final rule.

[231] The right cutpoint for the light truck curve was moved further to the right for MYs 2017-2021, so that more possible footprints would fall on the sloped part of the curve. In order to ensure that, for all possible footprints, future standards would be at least as high as MY 2016 levels, the final standards for light trucks for MYs 2017-2021 is the maximum of the MY 2016 target curves and the target curves for the give MY standard. This is defined further in the 2012 final rule. *See* 77 Fed. Reg. 62624, at 62699-700 (Oct. 15, 2012).

the curve is instead specified in gallons per mile (gpm). The slope, *c*, and the intercept, *d*, of the linear portion of the curve are specified as gpm per change in square feet, and gpm, respectively.

The min and max functions will take the minimum and maximum values within their associated parentheses. Thus, the max function will first find the maximum of the fitted line at a given footprint value and the lower asymptote from the perspective of gpm. If the fitted line is below the lower asymptote it is replaced with the floor, which is also the minimum of the floor and the ceiling by definition, so that the target in mpg space will be the reciprocal of the floor in mpg space, or simply, *a*. If, however, the fitted line is not below the lower asymptote, the fitted value is returned from the max function and the min function takes the minimum value of the upper asymptote (in gpm space) and the fitted line. If the fitted value is below the upper asymptote, it is between the two asymptotes and the fitted value is appropriately returned from the min function, making the overall target in mpg the reciprocal of the fitted line in gpm. If the fitted value is above the upper asymptote, the upper asymptote is returned is returned from the min function, and the overall target in mpg is the reciprocal of the upper asymptote in gpm space, or *b*.

In this way curves specified as constrained linear functions are specified by the following parameters:

a = upper limit (mpg)
b = lower limit (mpg)
c = slope (gpm per sq. ft.)
d = intercept (gpm)

The slope and intercept are specified as gpm per sq. ft. and gpm instead of mpg per sq. ft. and mpg because fuel consumption and emissions appear roughly linearly related to gallons per mile (the reciprocal of the miles per gallon).

a) NHTSA in MY 2008 and MY 2011 CAFE (constrained logistic)

For the MY 2011 CAFE rule, NHTSA estimated fuel economy levels by footprint from the MY 2008 fleet after normalization for differences in technology,[232] but did not make adjustments to reflect other vehicle attributes (*e.g.*, power-to-weight ratios). Starting with the technology-adjusted passenger car and light truck fleets, NHTSA used minimum absolute deviation (MAD) regression without sales weighting to fit a logistic form as a starting point to develop mathematical functions defining the standards. NHTSA then identified footprints at which to apply minimum and maximum values (rather than letting the standards extend without limit) and transposed these functions vertically (*i.e.*, on a gallons-per-mile basis, uniformly downward) to produce the promulgated standards. In the preceding rule, for MYs 2008-2011 light truck standards, NHTSA examined a range of potential functional forms, and concluded that, compared to other considered forms, the constrained logistic form provided the expected

[232] *See* 74 Fed. Reg. 14196, 14363-14370 (Mar. 30, 2009) for NHTSA discussion of curve fitting in the MY 2011 CAFE final rule.

and appropriate trend (decreasing fuel economy as footprint increases), but avoided creating "kinks" the agency was concerned would provide distortionary incentives for vehicles with neighboring footprints.[233]

b) MYs 2012-2016 Standards (constrained linear)

For the MYs 2012-2016 rule, potential methods for specifying mathematical functions to define fuel economy and CO_2 standards were reevaluated. These methods were fit to the same MY 2008 data as the MY 2011 standard. Considering these further specifications, the constrained logistic form, if applied to post-MY 2011 standards, would likely contain a steep mid-section that would provide undue incentive to increase the footprint of midsize passenger cars.[234] A range of methods to fit the curves would have been reasonable, and a minimum absolute deviation (MAD) regression without sales weighting on a technology-adjusted car and light truck fleet was used to fit a linear equation. This equation was used as a starting point to develop mathematical functions defining the standards. Footprints were then identified at which to apply minimum and maximum values (rather than letting the standards extend without limit). Finally, these constrained/piecewise linear functions were transposed vertically (*i.e.*, on a gpm or CO_2 basis, uniformly downward) by multiplying the initial curve by a single factor for each MY standard to produce the final attribute-based targets for passenger cars and light trucks described in the final rule.[235] These transformations are typically presented as percentage improvements over a previous MY target curve.

c) MYs 2017 and beyond standards (constrained linear)

The mathematical functions finalized in 2012 for MYs 2017 and beyond changed somewhat from the functions for the MYs 2012-2016 standards. These changes were made both to address comments from stakeholders, and to consider further some of the technical concerns and policy goals judged more preeminent under the increased uncertainty of the impacts of finalizing and proposing standards for model years further into the future.[236] Recognizing the concerns raised by full-line OEMs, it was concluded that continuing increases in the stringency of the light truck standards would be more feasible if the light truck curve for MYs 2017 and beyond was made steeper than the MY 2016 truck curve and the right (large footprint) cut-point was extended only gradually to larger footprints. To accommodate these considerations, the 2012 final rule finalized the slope fit to the MY 2008 fleet using a sales-weighted, ordinary least-squares regression, using a fleet that had technology applied to make the technology application across the fleet more uniform, and after adjusting the data for the effects of weight-to-footprint. Information from an updated MY 2010 fleet was also considered to support this decision. As the curve was vertically shifted (with fuel economy specified as mpg instead of gpm or CO_2

[233] *See* 71 Fed. Reg. 17556, 17609-17613 (Apr. 6, 2006) for NHTSA discussion of "kinks" in the MYs 2008-2011 light truck CAFE final rule (there described as "edge effects"). A "kink," as used here, is a portion of the curve where a small change in footprint results in a disproportionally large change in stringency.
[234] 75 Fed. Reg. at 25362.
[235] *See generally* 74 Fed. Reg. at 49491-96; 75 FR at 25357-62.
[236] The MYs 2012-2016 final standards were signed April 1st, 2010 — putting 6.5 years between its signing and the last affected model year, while the MYs 2017-2021 final standards were signed August 28th, 2012 — giving just more than nine years between signing and the last affected final standards.

emissions) upwards, the right cutpoint was progressively moved for the light truck curves with successive model years, reaching the final endpoint for MY 2021; this is further discussed and shown in Chapter 4.3 of the PRIA and Chapter [xxx] of the FRIA.

5. Reconsidering the mathematical functions for today's rulemaking

a) Why is it important to reconsider the mathematical functions?

By shifting the developed curves by a single factor, it is assumed that the underlying relationship of fuel consumption (in gallons per mile) to vehicle footprint does not change significantly from the model year data used to fit the curves to the range of model years for which the shifted curve shape is applied to develop the standards. However, it must be recognized that the relationship between vehicle footprint and fuel economy is not necessarily constant over time; newly developed technologies, changes in consumer demand, and even the curves themselves could influence the observed relationships between the two vehicle characteristics. For example, if certain technologies are more effective or more marketable for certain types of vehicles, their application may not be uniform over the range of vehicle footprints. Further, if market demand has shifted between vehicle types, so that certain vehicles make up a larger share of the fleet, any underlying technological or market restrictions which inform the average shape of the curves could change. That is, changes in the technology or market restrictions themselves, or a mere re-weighting of different vehicles types, could reshape the fit curves.

For the above reasons, the curve shapes were reconsidered in the proposal using the newest available data from MY 2016. With a view toward corroboration through different techniques, a range of descriptive statistical analyses were conducted that do not require underlying engineering models of how fuel economy and footprint might be expected to be related, and a separate analysis that uses vehicle simulation results as the basis to estimate the relationship from a perspective more explicitly informed by engineering theory was conducted as well. Despite changes in the new vehicle fleet both in terms of technologies applied and in market demand, the underlying statistical relationship between footprint and fuel economy has not changed significantly since the MY 2008 fleet used for the 2012 final rule; therefore, EPA and NHTSA proposed to continue to use the curve shapes fit in 2012. The analysis and reasoning supporting this decision follows.

b) What statistical analyses did EPA and NHTSA consider?

In considering how to address the various policy concerns discussed above, data from the MY 2016 fleet was considered, and a number of descriptive statistical analyses (i.e., involving observed fuel economy levels and footprints) using various statistical methods, weighting schemes, and adjustments to the data to make the fleets less technologically heterogeneous were performed. There were several adjustments to the data that were common to all of the statistical analyses considered.

With a view toward isolating the relationship between fuel economy and footprint, the few diesels in the fleet were excluded, as well as the limited number of vehicles with partial or

full electric propulsion; when the fleet is normalized so that technology is more homogenous, application of these technologies is not allowed. This is consistent with the methodology used in the 2012 final rule.

The above adjustments were applied to all statistical analyses considered, regardless of the specifics of each of the methods, weights, and technology level of the data, used to view the relationship of vehicle footprint and fuel economy. Table V-1Table V-1, below, summarizes the different assumptions considered and the key attributes of each. The analysis was performed considering all possible combinations of these assumptions, producing a total of eight footprint curves.

Table V-1 - Summary of Assumptions Considered in the Statistical Analysis of the Current Footprint-FE Relationship

Varying Assumptions	**Regression Type**		**Regression Weights**		**Technology Level**	
Alternatives Considered	OLS	MAD	Production-weighted	Model-weighted	Current Technology	Max. Technology
Details	Ordinary Least Squares Regression	Minimum Absolute Deviation Regression	Points weighted by production volumes of each model.	Equal weight for each model; collapses points with similar: footprint, FE, and curb weight.	Current MY 2016 tech., excluding: HEV, PHEV, BEV, and FCV.	Maximum tech. applied, excluding: HEV, PHEV, BEV, and FCV.
Key Attributes	Describes the average relationship between footprint and fuel economy; outliers can skew results.	Describes the median relationship between footprint and fuel economy; does not give outliers as much weight.	Tends towards higher-volume models; may systematically disadvantage manufacturers who produce fewer vehicles.	Tends towards the space of the joint distribution of fontprint and FE with the most models; gives low-volume models equal weight.	Describes current market, including demand factors; may miss changes in curve shape due to advanced technology application.	Captures relationship with homogenous technology application; may miss varying demand considerations for different segments.

(1) Current Technology Level Curves

The "current technology" level curves exclude diesels and vehicles with electric propulsion, as discussed above, but make no other changes to each model year fleet. Comparing

the MY 2016 curves to ones built under the same methodology from previous model year fleets shows whether the observed curve shape has changed significantly over time as standards have become more stringent. Importantly, these curves will include any market forces which make technology application variable over the distribution of footprint. These market forces will not be present in the "maximum technology" level curves: by making technology levels homogenous, this variation is removed. The current technology level curves built using both regression types and both regression weight methodologies from the MY 2008, MY 2010, and MY 2016 fleets, shown in more detail in Chapter 4.4.2.1 of the PRIA and Chapter [xxx] of the FRIA, support the curve slopes finalized in the 2012 final rule. The curves built from most methodologies using each fleet generally shift, but remain very similar in slope. This suggests that the relationship of footprint to fuel economy, including both technology and market limits, has not significantly changed.

(2) Maximum Technology Level Curves

As in prior rulemakings, technology differences between vehicle models were considered to be a significant factor producing uncertainty regarding the relationship between fuel consumption and footprint. Noting that attribute-based standards are intended to encourage the application of additional technology to improve fuel efficiency and reduce CO_2 emissions across the distribution of footprint in the fleet, approaches were considered in which technology application is simulated for purposes of the curve fitting analysis in order to produce fleets that are less varied in technology content. This approach helps reduce "noise" (i.e., dispersion) in the plot of vehicle footprints and fuel consumption levels and identify a more technology-neutral relationship between footprint and fuel consumption. The results of updated analysis for maximum technology level curves are also shown in Chapter 4.4.2.2 of the PRIA and Chapter [xxx] of the FRIA. Especially if vehicles progress over time toward more similar size-specific efficiency, further removing variation in technology application both better isolates the relationship between fuel consumption and footprint and further supports the curve slopes finalized in the 2012 final rule.

c) What other methodologies were considered?

The methods discussed above are descriptive in nature, using statistical analysis to relate observed fuel economy levels to observed footprints for known vehicles. As such, these methods are clearly based on actual data, answering the question "how does fuel economy appear to be related to footprint?" However, being independent of explicit engineering theory, they do not answer the question "how might one expect fuel economy to be related to footprint?" Therefore, as an alternative to the above methods, an alternative methodology was also developed and applied that, using full-vehicle simulation, comes closer to answering the second question, providing a basis either to corroborate answers to the first, or suggest that further investigation could be important.

As discussed in the 2012 final rule, several manufacturers have confidentially shared with the agencies what they described as "physics-based" curves, with each OEM showing significantly different shapes for the footprint-fuel economy relationships. This variation suggests that manufacturers face different curves given the other attributes of the vehicles in their

fleets (i.e., performance characteristics) and/or that their curves reflected different levels of technology application. In reconsidering the shapes of the proposed MYs 2021-2026 standards, a similar estimation of physics-based curves leveraging third-party simulation work form Argonne National Laboratories (ANL) was developed. Estimating physics-based curves better ensures that technology and performance are held constant for all footprints; augmenting a largely statistical analysis with an analysis that more explicitly incorporates engineering theory helps to corroborate that the relationship between fuel economy and footprint is in fact being characterized.

Tractive energy is the amount of energy it will take to move a vehicle.[237] Here, tractive energy effectiveness is defined as the share of the energy content of fuel consumed which is converted into mechanical energy and used to move a vehicle — for internal combustion engine (ICE) vehicles, this will vary with the relative efficiency of specific engines. Data from ANL simulations suggest that the limits of tractive energy effectiveness are approximately 25% for vehicles with internal combustion engines which do not possess integrated starter generator, other hybrid, plug-in, pure electric, or fuel cell technology.

A tractive energy prediction model was also developed to support today's proposal. Given a vehicle's mass, frontal area, aerodynamic drag coefficient, and rolling resistance as inputs, the model will predict the amount of tractive energy required for the vehicle to complete the Federal test cycle. This model was used to predict the tractive energy required for the average vehicle of a given footprint[238] and "body technology package" to complete the cycle. The body technology packages considered are defined in Table V-2Table V-2, below. Using the absolute tractive energy predicted and tractive energy effectiveness values spanning possible ICE engines, fuel economy values were then estimated for different body technology packages and engine tractive energy effectiveness values.

Table V-2 - Summary of Body Technology Packages Considered for Tractive Energy Analysis

Body Tech. Package	Mass Reduction Level	Aerodynamics Level	Roll Resistance Level
1	0%	0%	0%
2	0%	10%	10%
3	10%	10%	10%
4	10%	15%	20%
5	15%	20%	20%

[237] Thomas, J. "Drive Cycle Powertrain Efficiencies and Trends Derived from EPA Vehicle Dynamometer Results," *SAE Int. J. Passeng. Cars - Mech. Syst.* 7(4):2014, doi:10.4271/2014-01-2562. *Available at* https://www.sae.org/publications/technical-papers/content/2014-01-2562/ (last accessed June 15, 2018).

[238] The mass reduction curves used elsewhere in this analysis were used to predict the mass of a vehicle with a given footprint, body style box, and mass reduction level. The 'Body style Box' is 1 for hatchbacks and minivans, 2 for pickups, and 3 for sedans, and is an important predictor of aerodynamic drag. Mass is an essential input in the tractive energy calculation.

Chapter 6 of the PRIA and Chapter [xxx] of the FRIA show the resultant CAFE levels estimated for the vehicle classes ANL simulated for this analysis, at different footprint values and by vehicle "box." Pickups are considered 1-box, hatchbacks and minivans are 2-box, and sedans are 3-box. These estimates are compared with the MY 2021 standards finalized in 2012. The general trend of the simulated data points follows the pattern of the previous MY 2021 standards for all technology packages and tractive energy effectiveness values presented in the PRIA. The tractive energy curves are intended to validate the curve shapes against a physics-based alternative, and the analysis suggests that the curve shapes track the physical relationship between fuel economy and tractive energy for different footprint values.

Physical limitations are not the only forces manufacturers face; their success is dependent upon producing vehicles that consumers desire and will purchase. For this reason, in setting future standards, the analysis will continue to consider information from statistical analyses that do not homogenize technology applications in addition to statistical analyses which do, as well as a tractive energy analysis similar to the one presented above.

The relationship between fuel economy and footprint remains directionally discernable but quantitatively uncertain. Nevertheless, each standard must commit to only one function. Approaching the question "how is fuel economy related to footprint" from different directions and applying different approaches has given EPA and NHTSA confidence that the function applied here appropriately and reasonably reflects the relationship between fuel economy and footprint.

The agencies invited comments on this conclusion and the supporting analysis. IPI raised concerns that "…several dozen models (mostly subcompacts and sports cars) fall in the 30-40 square feet range, which are all subject to the same standards" and that "manufacturers of these models may have an incentive to decrease footprints as a compliance strategy, since doing so would not trigger more stringent standards."[239] NHTSA and EPA agree that, all else equal, downsizing the smallest cars (e.g., Chevrolet Spark, Ford Fiesta, Mini Cooper, Mazda MX-5, Porsche 911, Toyota Yaris) would most likely tend to degrade overall highway safety. At the same time, as discussed above, the agencies recognize that small vehicles do appear attractive to some market segments (although obviously the Ford Fiesta and Porsche 911 compete in different segments). Therefore, there is a tension between on one hand, avoiding standards that unduly encourage safety-eroding downsizing and, on the other, avoiding standards that unduly penalize the market for small vehicles. The agencies examined this issue, and note that the market for the smallest vehicles has not evolved at all as estimated in the analysis supporting the 2012 final rule, and attribute this more to fuel prices and consumer demand for larger vehicles than to attribute-based CAFE and CO_2 standards. For example, the market for vehicles with footprints less than 40 square foot was about 45% smaller in MY 2017 than in MY 2010. The agencies also found that among the smallest vehicle models produced throughout MYs 2010-2017, most have become larger, not smaller. For example, while the Mazda MX-5's footprint decreased by 0.1 square foot (0.3%) during that time, the MY 2017 versions of the Mini Cooper, Smart fortwo, Porsche 911, and Toyota Yaris had larger footprints than in MY 2010. With the market for very small vehicles shrinking, and with manufacturers not evidencing a tendency to make the

[239] IPI, NHTSA-2018-0067-12362, p. 14.

smallest vehicles even smaller, the agencies are satisfied that it would be unwise to change the target functions such that targets never stop becoming more stringent as vehicle footprint becomes ever smaller, because doing so could further impede an already-shrinking market.

B. No-action alternative

As in the proposal, the No-Action Alternative applies the augural CAFE and final CO_2 targets announced in 2012 for MYs 2021-2025. For MY 2026, this alternative applies the same targets as for MY 2025. The carbon dioxide equivalent of air conditioning refrigerant leakage credits, nitrous oxide, and methane emissions are included for compliance with the EPA standards for all model years under the no-action alternative.

Table V-3 - Characteristics of No-Action Alternative – Passenger Cars

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	50.83	53.21	55.71	58.32	61.07	61.07
b (mpg)	38.02	39.79	41.64	43.58	45.61	45.61
c (gpm per s.f.)	0.000442	0.000423	0.000404	0.000387	0.000370	0.000370
d (gpm)	0.00155	0.00146	0.00137	0.00129	0.00121	0.00121
CO2 Targets						
a (g/mi)	~~157.0464~~	~~150.0452~~	~~143.0440~~	~~157.0430~~	~~131.0422~~	~~131.0422~~
b (g/mi)	~~215.0220~~	~~205.0240~~	~~196.0200~~	~~188.0180~~	~~179.0158~~	~~179.0164~~
c (g/mi per s.f.)	~~3.843.93~~	~~3.693.76~~	~~3.543.59~~	~~3.43.41~~	~~3.263.29~~	~~3.263.29~~
d (g/mi)	~~-0.400~~	~~-1.140.8~~	~~-1.8-1.6~~	~~-2.5-2.3~~	~~-3.2-3.0~~	~~-3.2-3.0~~

Table V-4 - Characteristics of No-Action Alternative – Light Trucks

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	41.80	43.79	45.89	48.09	50.39	50.39
b (mpg)	25.25	26.29	27.53	28.83	30.19	30.19
c (gpm per s.f.)	0.000482	0.000461	0.000440	0.000421	0.000402	0.000402
d (gpm)	0.00416	0.00394	0.00373	0.00353	0.00334	0.00334
e (mpg)	35.41	35.41	35.41	35.41	35.41	35.41
f (mpg)	25.25	25.25	25.25	25.25	25.25	25.25
g (gpm per s.f.)	0.000455	0.000455	0.000455	0.000455	0.000455	0.000455
h (gpm)	0.00960	0.00960	0.00960	0.00960	0.00960	0.00960
CO_2 Targets						
a (g/mi)	195	186	176	168	159	159
b (g/mi)	335	321	306	291	277	277
c (g/mi per s.f.)	4.28	4.09	3.91	3.74	3.58	3.58
d (g/mi)	19.8	17.9	16.0	14.2	12.5	12.5
e (g/mi)	234	234	234	234	234	234
f (g/mi)	335	335	335	335	335	335

Commented [A94]: CHANGE AS SHOWN: Car targets in table corrected to be consistent with current standards. See 40 CFR 86.1818-12(c).

g (g/mi per s.f.)	4.04	4.04	4.04	4.04	4.04	4.04
h (g/mi)	68.1	68.1	68.1	68.1	68.1	68.1

In comments on the DEIS, CBD *et al.* indicated that it was appropriate for NHTSA to use the augural CAFE standards as the baseline No Action regulatory alternative.[240] However, CARB commented that the baseline regulatory alternative should include CARB's ZEV mandate, in part because EPA must consider "other regulations promulgated by EPA or other government entities;" and, according to CARB, there will be much more vehicle electrification in the future as manufacturers respond to market demand and also work to comply with the ZEV mandate.[241]

On the other hand, arguing for consideration of standards less stringent than those proposed in the NPRM, Walter Kreucher commented that rather than using the augural standards as the baseline, "a better approach would be to assume a clean sheet of paper and start from the existing 2016MY fleet and its associated standards as the baseline using 0%/year increases for both passenger cars and light trucks for MYs 2017-2026."[242] Similarly, AVE argued that because previously-promulgated standards for MYs 2018-2021 already present a significant challenge that "will likely require almost every automaker to continue using credits for compliance,... AVE believes this rulemaking should reset ...the current compliance baseline for cars and light trucks at MY 2018..."[243] BorgWarner commented similarly that "Beginning in MY 2018, standards should be reset to the levels the industry actually achieved. For MY 2018 and beyond, succeeding model year targets should be set with an annual rate of improvement defined by the slope of improvement the industry has achieved over the last six years.... Based on these data, our analysis suggests the most reasonable and logical rate of improvement falls between 2.0% to 2.6% for cars and trucks. Additionally, a single rate of improvement for the combined fleet should be considered."[244]

The No-Action Alternative represents expectations regarding the world in the absence of a proposal, accounting for applicable laws already in place. Although manufacturers are already making significant use of compliance credits toward compliance with even MY 2017 standards, the agencies are obligated to evaluate regulatory alternatives against the standards already in place through MY 2025. Similarly, even though manufacturers are already producing electric vehicles, EPA and NHTSA appropriately excluded California's ZEV mandate from the No-Action alternative for the NPRM, for several reasons. First, the ZEV mandate is not Federal law; second, as described in the proposal and subsequently finalized in regulatory text, the ZEV mandate is expressly and impliedly preempted by EPCA; third, EPA proposed to withdraw the waiver of CAA preemption in the NPRM and subsequently finalized this withdrawal. Accordingly, the agencies have, therefore, appropriately excluded the ZEV mandate from the No-Action alternative. However, as discussed below, the agencies' analysis does account for the potential that under every regulatory alternative, including the No-Action Alternative, vehicle

[240] CBD *et al.*, NHTSA-2018-0067-12123, Attachment 1, at 13.
[241] CARB, NHTSA-2018-0067-11873, at 124-125.
[242] Kreucher, W., NHTSA-2018-0067-0444, at 8.
[243] AVE, NHTSA-2018-0067-11696, at 8-9.
[244] BorgWarner, NHTSA-2018-0067-11895, at 3, 6.

electrification could increase in the future, especially if batteries become less expensive as gasoline becomes more expensive.

C. Action alternatives

1. Alternatives in final rule

The table below shows the different alternatives evaluated in today's notice.

Table V-5 - Regulatory Alternatives Currently under Consideration

Alternative	Change in stringency
Baseline/ No-Action	MY 2021 standards remain in place; MYs 2022-2025 augural CAFE standards are finalized and CO_2 standards remain unchanged; MY 2026 standards are set at MY 2025 levels
1 (Proposed)	Existing standards through MY 2020, then 0%/year increases for both passenger cars and light trucks, for MYs 2021-2026
2	Existing standards through MY 2020, then 0.5%/year increases for both passenger cars and light trucks, for MYs 2021-2026
3 (Preferred)	Existing standards through MY 2020, then 1.5%/year increases for both passenger cars and light trucks, for MYs 2021-2026
4	Existing standards through MY 2020, then 1%/year increases for passenger cars and 2%/year increases for light trucks, for MYs 2021-2026
5	Existing standards through MY 2021, then 1%/year increases for passenger cars and 2%/year increases for light trucks, for MYs 2022-2026
6	Existing standards through MY 2020, then 2%/year increases for passenger cars and 3%/year increases for light trucks, for MYs 2021-2026
7	Existing standards through MY 2021, then 2%/year increases for passenger cars and 3%/year increases for light trucks, for MYs 2022-2026

With one exception, the alternatives considered in the NPRM included the changes in stringency for the above alternatives. Alternative 3, the preferred alternative, is newly included for today's notice.[245]

Regulations regarding implementation of NEPA requires agencies to "rigorously explore and objectively evaluate all reasonable alternatives, and for alternatives which were eliminated from detailed study, briefly discuss the reasons for their having been eliminated."[246] This does not amount to a requirement that agencies evaluate the widest conceivable spectrum of alternatives. For example, a State considering adding a single travel lane to a preexisting section of highway would not be required to consider adding three lanes, or to consider dismantling the highway altogether.

Among thousands of individual comments that mentioned the proposed standards very generally, some comments addressed the range and definition of these regulatory alternatives in

[245] As the agencies indicated in the NPRM, they were considering and taking comment "on a wide range of alternatives and have specifically modeled eight alternatives." 83 FR at 42990 (Aug. 24, 2018). The preferred alternative in this final rule was within the range of alternatives considered in the proposal, although it was not specifically modeled at that time. This issue is discussed in further detail below.

[246] 40 CFR 1502.14

specific terms, and these specific comments include comments on the stringency, structure, and particular provisions defining the set of regulatory alternatives under consideration.

As discussed throughout today's notice, the agencies have updated and otherwise revised many aspects of the analysis. The agencies have also reconsidered whether the set of alternatives studied in detail should be expanded to include standards less stringent than the proposal's preferred alternative, or to include standards more stringent than the proposal's no-action alternative. On one hand, comments from Walter Kreucher and AVE cited above indicate the agencies should consider relaxing standards below MY 2020 levels, and CEI challenged the agencies' failure to include less-stringent alternatives in the following comments on this question:

> DOT failed to consider the possibility of freezing CAFE at an even more lenient standard than currently exists, nor did it consider making its proposed freeze take effect sooner than MY 2020. However, as DOT's own analysis strongly indicates, doing so would lead to even greater benefits and an even greater reduction in CAFE-related deaths and injuries. In short, DOT's failure to consider this possibility is arbitrary and capricious. It has an opportunity to remedy this in its final rule, and it should do so by selecting a standard that is even more lenient than the one it proposed.... It should have gone beyond its original set of alternatives and examined less stringent ones as well – until it found one that, for some reason or another, failed to produce greater safety benefits or failed to meet the statutory factors.[247]

On the other hand, a coalition of ten environmental advocacy organizations stated that the agencies should consider alternatives more stringent than those defining the baseline no action alternative, arguing that in light of CEQ guidance and the 2018 IPCC report on climate change, "the increasing danger, increasing urgency, and increasing importance of vehicle emissions all rationally counsel for strengthening emission standards."[248] CBD *et al.* observe that "none of these alternatives [considered in the NPRM] increases fuel economy in comparison with the No Action Alternative, none conserves energy..." and go on to assert that "none represents maximum feasible CAFE standards."[249] Similarly, EDF commented that "...given its clear statutory directive to maximize fuel savings, NHTSA should have considered a range of alternatives that would be more protective than the existing standards,"[250] and three State agencies in Minnesota commented that "more stringent standards are consistent with EPCA's purpose of energy conservation and the CAA's purpose of reducing harmful air pollutants."[251] The North Carolina Department of Environmental Quality acknowledged the agencies' determination in the proposal that alternatives beyond the augural standards might be

[247] CEI, NHTSA-2018-0067-12015, at 1.
[248] CBD, *et al.*, NHTSA-2018-0067-12057 p. 10. Also, see comments from Senator Tom Carper, NHTSA-2018-0067-11910, at 8-9, and from UCS, NHTSA-2018-0067-12039, at 3.
[249] CBD, *et al.*, NHTSA-2018-0067-12123, at 12-13.
[250] EDF, NHTSA-2018-0067-11996, at 20.
[251] Minnesota Pollution Control Agency, Department of Transportation, and Department of Health, NHTSA-2018-0067-11706, at 5.

economically impracticable, but nevertheless argued that "alternatives that exceed the stringency of the current standards are consistent with EPCA's purpose"[252] In oral testimony before the agencies, the New York State Attorney General also indicated that the agencies should consider alternatives more stringent than the augural standards.[253] A coalition of States and cities commented that "at a minimum, the existing standards should be left in place, but EPA should also consider whether to make the standards more stringent, not less, just as it has done in prior proposals."[254] More specifically, ~~through~~ International Mosaic, ~~an online blog, some otherwise-anonymous individuals~~ commented that the agencies must "fully and publicly consider a few options that require at least a seven annual percent [sic] improvement in vehicle fleet mileage."[255] In comments on the DEIS, CBD, *et al.* went further, commenting that "NHTSA's most stringent alternative must be set at no lower than a 9 percent improvement per year."[256] Most manufacturers who commented on stringency did not identify specific regulatory alternatives that the agencies should consider, although Honda suggested that standards be set to increase in stringency at 5% annually for both passenger cars and light trucks throughout model years 2021-2026.[257,258]

Commented [A95]: CHANGE AS SHOWN: As noted elsewhere, commenting on the individuals or membership of organizations gives the appearance of bias, and is not necessary for responding on substance.

The agencies carefully considered these comments to expand the range of stringencies to be evaluated as possible candidates for promulgation. To inform this consideration, the agencies used the CAFE model to examine a progression of stringencies extending outside the range presented in the proposal and draft EIS, and as a point of reference, using a case that reverts to MY 2018 standards starting in MY 2021. Scenarios included in this initial screening exercise ranged as high as increasing annually at 9.5% during MYs 2021-2026, reaching average CAFE and CO_2 requirements of 66 mpg and 119 g/mi, respectively. Results of this analysis are presented in the following tables and charts. Focusing on MY 2029, the tables show average required and achieved CAFE (as mpg) and CO_2 (as g/mi) levels for each scenario, along with average per-vehicle costs (in 2018 dollars, relative to retaining MY 2017 technologies). The proposed (0%/0%), final (1.5%/1.5%), and baseline augural standards are shown in bold type. The charts present the same results on a percentage basis, relative to values shown below for the scenario that reverts to MY 2018 standards starting in MY 2021.

For example, reverting to the MY 2018 CAFE standards starting in MY 2021 yields an average CAFE requirement of 35 mpg by MY 2029, with the industry exceeding that standard by 5 mpg at an average cost of $1,254 relative to MY 2017 technology. Under the augural standards, the MY 2029 requirement increases to 47 mpg, the average compliance margin falls to 1 mpg, and the average cost increases to $2,850. In other words, compared to the scenario that reverts to MY 2018 stringency starting in MY 2021, the augural standards increase stringency by

[252] North Carolina Department of Environmental Quality, NHTSA-2018-0067-12025, at 37-38.
[253] New York State Attorney General, Testimony of Austin Thompson, NHTSA-2018-0067-12305, at 13.
[254] NHTSA-2018-0067-11735, at 49.
[255] International Mosaic NHTSA-2018-0067-11154, at 1
[256] CBD, *et al.*, NHTSA-2018-0067-12123, at 17.
[257] Honda, NHTSA-2018-0067-12019, EPA-HQ-OAR-2018-0283, at 54.
[258] In model year 2021, the baseline standards for passenger cars and light trucks increase by about 4% and 6.5%, respectively, relative to standards for model year 2020. Depending on the composition of the future new vehicle fleet (i.e., the footprints and relative market shares of passenger cars and light trucks), this amounts to an overall average stringency increase of about 5.5% relative to model year 2020.

34% (from 35 to 47 mpg), increase average fuel economy by 20% (from 40 to 48 mpg), and increase costs by 127% (from $1,254 to $2,850).

As indicated in the following two charts, the reality of diminishing returns clearly applies in both directions. On one hand, relaxing stringency below the proposed standards by reverting to MY 2018 or MY 2019 standards reduces average MY 2029 costs by only modest amounts ($0-$145). As discussed in Section VII, the agencies' updated analysis indicates that the proposed standards would fall short of EPCA's requirement that standards be set at the maximum feasible levels considering the statutory factors~~, and short of the CAA's requirement that standards be reasonable and appropriate~~. If further relaxation of standards appeared likely to yield more significant cost reductions, it is conceivable that such savings could outweigh further foregoing of energy and climate benefits. However, this screening analysis does not show dramatic cost reductions. Therefore, the agencies did not include these two less stringent alternatives in the detailed analysis presented in Section VII.

Commented [A96]: CHANGE AS SHOWN: The references to the CAA here are not correct; EPA suggests that all discussion of how the alternatives are evaluated under the CAA be contained in the Justification of Standards section VIII, and not in this discussion of alternatives.

On the other hand, increases in stringency beyond the baseline augural standards show costs continuing to accrue much more rapidly than CAFE and CO_2 improvements. Considering that, as discussed below in Section VII, even the no action alternative is already well beyond levels that can be supported under ~~the CAA and~~ EPCA. If further stringency increases appeared likely to yield more significant additional energy and environmental benefits, it is conceivable that these could outweigh these significant additional cost increases. However, this screening analysis shows no dramatic acceleration of energy and environmental benefits. Therefore, the agencies did not include stringencies beyond the augural standards in the detailed analysis presented in Section VII.

Commented [A97]: REVISE: The argument presented here – that stringency increases beyond the augural standards can only be supported if energy and environmental benefits accelerate – is only persuasive if two things are true: 1) the augural standards have ALREADY maximized net benefits, and 2) that the administrator's decision is solely based on consideration of net benefits.

However, both of those things are NOT true. As NHTSA's updated model and inputs now show, net benefits continue to increase with stringencies beyond the Augural standards (consistent with EPA's finding in the 2017 FD). Furthermore, the Administrator would have discretion to support standards more or less stringent, even if those standards do not maximize net benefits.

Table V-6 - Average MY 2029 Required and Achieved CAFE Levels (mpg) and Average MY 2029 Per-Vehicle Costs (2018 $) under a Range of Stringency Increases

Scenario	Average Required CAFE (mpg)	Average Achieved CAFE (mpg)	Average Cost (2018 $)
Revert to MY 2018 Standards Starting MY 2021	35	40	1,254
Revert to MY 2019 Standards Starting MY 2021	36	41	1,306
0.00%/y PC and 0.00%/y LT During 2021-2026	**37**	**41**	**1,399**
0.50%/y PC and 0.50%/y LT During 2021-2026	38	41	1,425
1.50%/y PC and 1.50%/y LT During 2021-2026	**40**	**42**	**1,656**
2.50%/y PC and 2.50%/y LT During 2021-2026	43	44	1,953
3.50%/y PC and 3.50%/y LT During 2021-2026	45	47	2,451
Augural Standards	**47**	**48**	**2,850**
4.50%/y PC and 4.50%/y LT During 2021-2026	48	49	3,051
5.50%/y PC and 5.50%/y LT During 2021-2026	51	52	3,641
6.50%/y PC and 6.50%/y LT During 2021-2026	55	56	4,238
7.50%/y PC and 7.50%/y LT During 2021-2026	58	59	4,923
8.50%/y PC and 8.50%/y LT During 2021-2026	62	63	6,223

Commented [A98]: REVISE: This needs to be updated. The cost numbers presented here do not seem consistent with the NHTSA's updated analysis.

9.50%/y PC and 9.50%/y LT During 2021-2026	66	66	7,810

Table V-7 - Average MY 2029 Required and Achieved CO_2 Levels (g/mi) and Average MY 2029 Per-Vehicle Costs (2018 $) under a Range of Stringency Increases

Scenario	Average Required CO_2 (g/mi)	Average Achieved CO_2 (g/mi)	Average Cost (2018 $)
Revert to MY 2018 Standards Starting MY 2021	238	208	1,239
Revert to MY 2019 Standards Starting MY 2021	232	208	1,246
0.00%/y PC and 0.00%/y LT During 2021-2026	**224**	**206**	**1,289**
0.50%/y PC and 0.50%/y LT During 2021-2026	218	205	1,310
1.50%/y PC and 1.50%/y LT During 2021-2026	**204**	**199**	**1,501**
2.50%/y PC and 2.50%/y LT During 2021-2026	191	190	1,831
3.50%/y PC and 3.50%/y LT During 2021-2026	180	178	2,302
Augural Standards	**175**	**173**	**2,560**
4.50%/y PC and 4.50%/y LT During 2021-2026	169	167	2,843
5.50%/y PC and 5.50%/y LT During 2021-2026	158	156	3,491
6.50%/y PC and 6.50%/y LT During 2021-2026	148	146	4,122
7.50%/y PC and 7.50%/y LT During 2021-2026	138	136	4,810
8.50%/y PC and 8.50%/y LT During 2021-2026	128	127	5,440
9.50%/y PC and 9.50%/y LT During 2021-2026	119	119	6,079

Commented [A99]: **REVISE:** This needs to be updated. The cost numbers presented here do not seem consistent with the NHTSA's updated analysis.

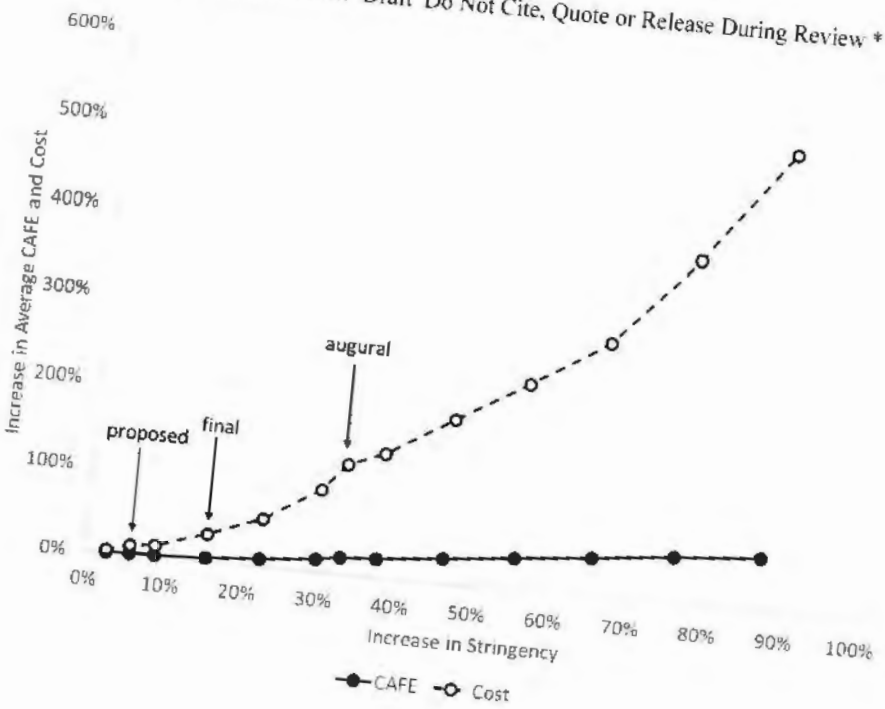

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Figure V-1 - Increase in Average CAFE and Cost (MY 2029) versus Increase in Stringency (as Average Required mpg in MY 2029) of CAFE Standards

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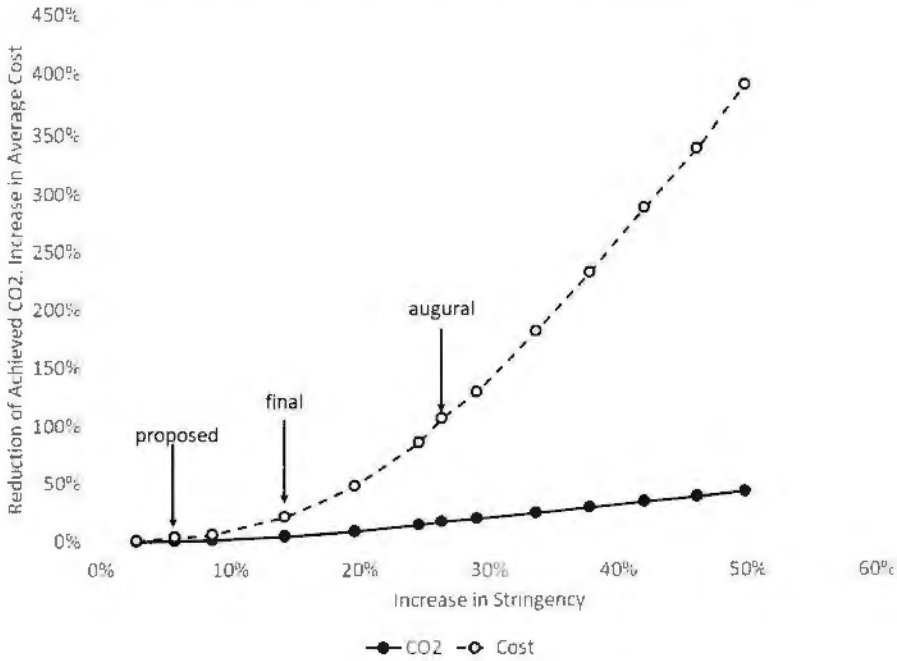

Figure V-2 - CO_2 Reduction and Cost Increases versus (MY 2029) Increase in Stringency

Specific to model year 2021, some commenters argued that EPCA's lead time requirement prohibits NHTSA from revising CAFE standards for model year 2021.[259] Regarding the revision of standards for model year 2021, NHTSA did consider EPCA's lead time requirement, and determined that while the agency would need to finalize a stringency increase at least 18 months before the beginning of the first affected model year, the agency can finalize a stringency decrease closer (or even after) the beginning of the first affected model year. The agency's reasoning is explained further in Section VIII. Therefore, NHTSA did not change regulatory alternatives to avoid any relaxation of stringency in model year 2021.

The Auto Alliance stated that "the truck increase rate should be no greater than the car rate of increase and should be the 'equivalent task' per fleet".[260] Supporting these Alliance

[259] State of California, et al., NHTSA-2018-0067-11735, at 78.; CBD, et al., NHTSA-2018-0067-12000, Appendix A, at 66.; National Coalition for Advanced Transportation, NHTSA-2018-0067-11969, at 46.
[260] Alliance, NHTSA-2018-0067-12073, at 7-8

comments, FCA elaborated by commenting that "(1) in MY2017, the latest data we have available, most trucks have a larger gap to standards than cars, and (2) all of the truck segments are challenged because consumers are placing a greater emphasis on capability than fuel economy."[261] Similarly, Ford commented that "... the rates of increase in the stringency of the standards should remain equivalent between passenger cars and light duty trucks."[262] Other commenters expressed general support for equalizing the rates at which the stringencies of passenger car and light truck standards increase.[263]

For the final rule, the agencies have added an alternative in which stringency for both cars and trucks increases at 1.5%. This is consistent with comments received requesting that both fleets' standards increase in stringency by the same amount, and 1.5% represents a rate of increase within the range of rates of increase considered in the NPRM.

Throughout the NPRM, the agencies described their consideration as covering a range of alternatives.[264] The preferred alternative for this final rule, an increase in stringency of 1.5% for both cars and trucks, falls squarely within the range of alternatives proposed by the agencies.

The NPRM alternatives were bounded on the upper end by the baseline/no action alternative, and the proposed alternative on the lower end (0% per year increase in stringency for both cars and trucks). For passenger cars, the agencies considered a range of stringency increases between 0% and 2% per year for passenger cars, in addition to the baseline/no action alternative. For light trucks, the agencies considered a range of stringency increases between 0% and 3% per year, in addition to the baseline/no action alternative.

The agencies considered the same range of alternatives for this final rule. As with the proposal, the alternatives for stringency are bounded on the upper end by the baseline/no action alternative and on the lower end by 0% per year increases for both passenger cars and light trucks. Consistent with the proposal, for this final rule, the agencies considered stringency increases of between 0 and 2% per year for passenger cars and between 0 and 3% per year for light trucks, in addition to the baseline/no action alternative.

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[261] FCA, NHTSA-2018-0067-11943, at 46-47.
[262] Ford, NHTSA-2018-0067-11928, at 3.
[263] See, e.g., Global, NHTSA-2018-0067-12032, at 4; NADA, NHTSA-2018-0067-12064, at 13; BorgWarner, NHTSA-2018-0067-11895, at 6.
[264] 83 FR at 42986 (Aug. 24, 2018) (explaining, in "Summary" section of NPRM, that "comment is sought on a range of alternatives discussed throughout this document"); *id.* at 42988 (stating that the agencies are "taking comment on a wide range of alternatives, including different stringencies and retaining existing CO2 standards and the augural CAFE standards"); 42990 ("As explained above, the agencies are taking comment on a wide range of alternatives and have specifically modeled eight alternatives (including the proposed alternative) and the current requirements (i.e., baseline/noaction)."); 43197 ("[T]oday's notice also presents the results of analysis estimating impacts under a range of other regulatory alternatives the agencies are considering."); 43229 (explaining that "technology availability, development and application, if it were considered in isolation, is not necessarily a limiting factor in the Administrator's selection of which standards are appropriate within the range of the Alternatives presented in this proposal."); 43369 ("As discussed above, a range of regulatory alternatives are being considered.").

While it was not specifically modeled in the NPRM, the new preferred alternative of an increase in stringency of 1.5% for both cars and trucks was well within the range of alternatives considered. The proposal described the alternatives specifically modeled as options for the agencies, but also gave notice that they did not limit the agencies in selecting from among the range of alternatives under consideration.[265]

The agencies explained in the proposal that they were "taking comment on a wide range of alternatives and have specifically modeled eight alternatives."[266] As with the proposal, for the final rule, the agencies specifically modeled the upper and lower bounds of the baseline/no action alternative and 0% per year stringency increases for both passenger cars and light trucks. In both the proposal and the final rule, the agencies also modeled a stringency increase of 2% per year for passenger cars and 3% per year for light trucks, as well as a variety of other specific increases between 0 and 2% for passenger cars and 0 and 3% for light trucks.

The specific alternatives the agencies modeled for the final rule reflect their consideration of public comments. As discussed above, multiple commenters expressed support for equalizing the rates at which the stringencies of passenger car and light truck standards increase. To help the agencies evaluate alternatives that include the same stringency increase for passenger cars and light trucks, three of the seven alternatives (in addition to the baseline/no action alternative) that the agencies specifically modeled for the final rule included the same stringency increase for passenger cars and light trucks. This includes the new preferred alternative of an increase in stringency of 1.5% for both cars and trucks. This alternative, and all others specifically modeled for the final rule, falls within the range of alternatives for stringency considered by the agencies in the proposal.

Beyond these stringency provisions discussed in the NPRM, the agencies also sought comment on a number of additional compliance flexibilities for the programs, as discussed in Section IX.

2. Additional alternatives suggested by commenters

Beyond the comments discussed above regarding the shapes of the functions defining fuel economy and CO_2 targets, regarding the inclusion of non-CO_2 emissions, and regarding the stringencies to be considered, the agencies also received a range of other comments regarding regulatory alternatives.

Some of these additional comments involved how CAFE and CO_2 standards compare to one another for any given regulatory alternative. With a view toward maximizing harmonization

[265] *See, e.g.*, 83 FR at 43003 (Aug. 24, 2018) ("These alternatives were examined because they will be considered as options for the final rule. The agencies seek comment on these alternatives, seek any relevant data and information, and will review responses. That review could lead to the selection of one of the other regulatory alternatives for the final rule or some combination of the other regulatory alternatives (e.g., combining passenger cars standards from one alternative with light truck standards from a different alternative)."); *id.* at 43229 (describing a factor relevant to "the Administrator's selection of which standards are appropriate within the range of the Alternatives presented in this proposal").

[266] 83 FR at 42990 (Aug. 24, 2018).

of the standards, the Alliance, supported by some of its members' individual comments, indicated that "to the degree flexibilities and incentives are not completely aligned between the CAFE and [CO_2] programs, there must be an offset in the associated footprint-based targets to account for those differences. Some areas of particular concerns are air conditioning refrigerant credits, and incentives for advanced technology vehicles. The Alliance urges the Agencies to seek harmonization of the standards and flexibilities to the greatest extent possible…."[267]

On the other hand, discussing consideration of compliance credits but making a more general argument, the NYU Institute for Policy Integrity commented that "…EPA is not allowed to set lower standards just for the sake of harmonization; to the contrary, full harmonization may be inconsistent with EPA's statutory responsibilities."[268] Similarly, ACEEE argued that "any consideration of an extension or expansion of credit provisions under the [carbon dioxide] or CAFE standards program should take as a starting point the assumption that the additional credits will allow the stringency of the standards to be increased."[269]

EPCA's requirement that NHTSA set standards at the maximum feasible levels is separate and "wholly independent" from the CAA's requirement, per *Massachusetts v. EPA*, that EPA issue regulations addressing pollutants that EPA has determined endanger public health and welfare.[270] Nonetheless, as recognized by the Supreme Court, "there is no reason to think the two agencies cannot both administer their obligations and yet avoid inconsistency."[271] This conclusion was reached despite the fact that EPCA has a range of very specific requirements about how CAFE standards are to be structured, how manufacturers are to comply, what happens when manufacturers are unable to comply, and how NHTSA is to approach setting standards, and despite the fact that the CAA has virtually no such requirements. This means that while nothing about either EPCA or the CAA, much less the combination of the two, guarantees "harmonization" defining "One National Program," the agencies are expected to be able to work out the differences.

~~Since tailpipe CO_2 standards are *de facto* fuel economy standards, the more differences there are between CO_2 and CAFE standards and compliance provisions, the more challenging it is for manufacturers to plan year-by-year production that responses to both, and the more difficult it is for affected stakeholders and the general public to understand regulation in this space. Therefore, even if the two statutes, taken together, do not guarantee "full harmonization," steps toward greater harmonization help with compliance planning and transparency—and~~ The agencies have never suggested that it would be possible to completely "harmonize" the requirements of EPCA and the requirements of the CAA in the sense that requirements for one statute would entirely match requirements for the other. Since the initial 2010 final rule setting standards for the model years 2012-2016 the agencies have understood that such a 100% overlap would not be possible given differences in statutory authority. At the same time, the agencies have also recognized that there would be significant advantages to manufacturers, stakeholders, and the general public from implementing the two statutes in a carefully coordinated and

Commented [A102]: CHANGE AS SHOWN: In this and next several paragraphs, EPA is correcting references to the CAA with text that is accurate and we believe more appropriate characterization of harmonization.

[267] Alliance, NHTSA-2018-0067-12073, at 40. See also FCA, NHTSA-2018-0067-11943, at 6-7.
[268] IPI, NHTSA-2018-0067-12213, at 21.
[269] ACEEE, NHTSA-2018-0067-12122, at 3.
[270] Massachusetts v. EPA, 549 U.S. 497, 532 (2007).
[271] *Id.*

harmonized way. Notwithstanding a lack of identicality between the programs, by carefully coordinating and harmonizing requirements, the agencies can meet the expectations set forth by the Supreme Court that the agencies avoid inconsistencies between the programs.

The agencies have taken important steps toward doing so. For example, the ageancies have harmonized the form of the standards -- EPA has adopted separate footprint-based CO_2 standards for passenger cars and light trucks -- and also the definitions of passenger cars and light trucks. EPA has also, and has redefined CAFE calculation procedures to introduce recognition for the application of real-world fuel-saving technology that is not captured with traditional EPA two-cycle compliance testing. Detailed aspects of both sets of standards and corresponding compliance provisions are discussed at length in Section IX. The agencies never set out with the primary goal of achieving "full harmonization," such that both sets of standards would lead eachimpose the exact same requirements on manufacturers to respond in exactly the same way in every model year.[222] For example, EPA did not adopt the EPCA requirement that domestic passenger car fleets each meet a minimum standard, or the EPCA cap on compliance credit transfers between passenger car fleets. On the other hand, EPA also did not adopt the EPCA civil penalty provisions that have allowed some manufacturers to pay civil penalties as an alternative method of meeting EPCA obligations. These and other differences provide that even *if* CAFE and CO_2 standards are "mathematically" harmonized, for any given manufacturer, the two sets of standards will not be identically burdensome in each model year. Inevitably, one standard will be more challenging than the other, varying over time, between manufacturers, and between fleets. As a practical matter, standards will apply in a different ways over time, between manufacturers, and between fleets. This means manufacturers need to have compliance plans for both sets of standards.

In 2012, recognizing that EPCA provides no clear basis to address HFC, CH_4, or N_2O emissions directly, the agencies "offset" CO_2 targets from fuel economy targets (after converting the latter to a CO_2 basis) by the amounts of credit EPA anticipated manufacturers would, on average, earn in each model years by reducing A/C leakage and adopting refrigerants with reduced GWPs. In 2012, EPA assumed that by 2021, all manufacturers would be earning the maximum available credit, and EPA's analysis assumed that all manufacturers would make progress at the same rate. However, as discussed above, data highlighted in comments by Chemours, Inc., demonstrate that actual manufacturers' adoption of lower-GWP refrigerants thus far ranges widely, with some manufacturers (e.g., Nissan) having taken no such steps to move toward lower-GWP refrigerants, while others (e.g., JLR) have already applied lower-GWP refrigerants to all vehicles produced for sale in the U.S. Therefore, at least in practice, HFC provisions thus far continue to leave a gap (in terms of harmonization) between the two sets of standards. The proposal would have taken the additional step of decoupling provisions regarding HFC (i.e., A/C leakage credits), CH_4, and N_2O emissions from CO_2 standards, addressing these in separate regulations to be issued in a potential new proposal. As discussed above, EPA didis not finalizeing this proposal. Accordingly, for the regulatory alternatives considered today, EPA

[222] Full harmonization would mean that, for example, if Ford would do some set of things over time in response to CAFE standards in isolation, it would do exactly the same things on exactly the same schedule in response to CO2 standards in isolation.

has reinstated offsets of CO_2 targets from fuel economy targets, reflecting the assumption that all manufacturers will be earning the maximum available A/C leakage credit by MY 2021.

In addition to general comments on harmonization, the agencies received a range of comments on specific provisions—especially involving "flexibilities"—that may or may not impact harmonization. With a view toward encouraging further electrification, NCAT proposed that EPA extend indefinitely the exclusion of upstream emissions from electricity generation, and also extend and potentially restructure production multipliers for PHEVs, EVs, and FCVs.[273] On the other hand, connecting its comments back to the stringency of standards, NCAT also commented that "…expansion of compliance flexibilities in the absence of any requirement to improve [CO_2] reduction or fuel economy (as under the agencies' preferred option) could result in an effective deterioration of existing [CO_2] and fuel economy performance, as well as little or no effective support for advanced vehicle technology development or deployment."[274] Global Automakers indicated that the final rule "should include a package of programmatic elements that provide automakers with flexible compliance options that promote the full breadth of vehicle technologies," such options to include the extension of "advanced technology" production multipliers through MY 2026, the indefinite exclusion of emissions from electricity generation, the extension to passenger cars of credits currently granted for the application of "game changing" technologies (e.g., HEVs) only to full-size pickup trucks, an increase (to 15 g/mi) of the cap on credits for off-cycle technologies, an updated credit "menu" of off-cycle technologies, and easier process for handling applications for off-cycle credits.[275] The Alliance also called for expanded sales multipliers and a permanent exclusion of emissions from electricity generation.[276] Walter Kreucher recommended the agencies consider finalizing the proposed standards but also keeping the augural standards as "voluntary targets" to " provide compliance with the statutes and an aspirational goal for manufacturers."[277]

The agencies have carefully considered these comments, and have determined that the current suite of "flexibilities" generally provide ample incentive more rapidly to develop and apply advanced technologies and technologies that produce fuel savings and/or CO_2 reductions that would otherwise not count toward compliance. The agencies also share some stakeholders' concern that expanding these flexibilities could increase the risk of "gaming" that would make compliance less transparent and would unduly compromise energy and environmental benefits. Nevertheless, as discussed in Section IX, EPA is adopting new multiplier incentives for natural gas vehicles. EPA is also finalizing some changes to procedures for evaluating applications for off-cycle credits, and expects these changes to make this process more accurate ~~rigorous (i.e., less susceptible to potential "gaming")~~ and more efficient. Also, EPA is revising its regulations to ~~remove requirements that~~not require manufacturers to account for upstream emissions associated with electricity use for electric vehicles and plug-in hybrid electric vehicles through model year 2026; compliance will instead be based on tailpipe emissions performance only.~~recognizing that while manufacturers have introduced many battery-electric vehicle~~

Commented [A103]: **CHANGE AS SHOWN**: EPA updated this paragraph to reflect the EPA multiplier for NGVs, and other changes correct references to the EPA program.

[273] NCAT, NHTSA-2018-0067-11969, at 3-5
[274] *Id.*
[275] Global Automakers, NHTSA-2018-0067-12032, at 4 *et seq.*
[276] Alliance, NHTSA-2018-0067-12073, at 8.
[277] Kreucher, W., NHTSA-2018-0067-0444, at 9.

~~offerings for the U.S., market demand and adoption has thus far been lackluster. EPA is today issuing regulations that delay the inclusion of emissions from electricity generation until model year 2027.~~ As discussed below, even with this change, and even accounting for continued increases in fuel prices and reductions in battery prices, BEVs are ~~likely~~ projected in this final rule analysis to continue to account for less than 5 percent of new light vehicle sales in the U.S. through model year 2026. This means that the impact of upstream emissions from electricity use on the projected CO_2 reductions associated with the standards is ~~although the 0 g/mi treatment of electricity causes EPA's program to over represent the ultimate environmental performance of its CO_2 standards, this aspect of such overrepresentation is likely~~ expected to remain small. Regarding comments suggesting that the ~~proposed finalization of~~ augural standards should be finalized as "voluntary targets," the agencies have determined that having such targets exist alongside actual regulatory requirements would be~~, at best, disingenuous~~ unnecessary and confusing.

Commented [A104]: REVISE: The conclusion that upstream impacts will be small is not supported by the projected electrification levels across all the years considered in the CAFE analysis (rather than simply 2026 referenced here.) Under the Augural standards, plug-in vehicles make up 11% of the fleet in MY2029, 26% in MY2040, and 73% in MY2050.

Beyond these additional proposals, some commenters' proposals clearly fell outside authority provided under EPCA or the CAA. Ron Lindsay recommended the agencies "consider postponing the rule changes until the U.S. can establish a legally binding national and international carbon budget and a binding mechanism to adhere to it."[278] EPCA requires NHTSA to issue standards for MY 2022 by April 1, 2020, and the agencies believe that it is appropriate to issue final~~ize~~ and revised CAFE and GHG standards for MYs 2021-2026 at this time ~~and previously-issued EPA regulations commit EPA to revisiting MY 2021-2025 standards on a similar schedule.~~ These statutory and regulatory provisions do not include a basis to delay decisions pending an international negotiation for which prospects and schedules are both unknown.

SCAQMD, supported by Shyam Shukla, indicated that the agencies should consider an alternative that keeps the waiver for California's CO_2 standards in place.[279] NCAT and the North Carolina DEQ offered similar comments and CBD, *et al.* commented that "among the set of more stringent alternatives that NEPA requires the agency to consider, NHTSA must include action alternatives that retain the standards California and other states have lawfully adopted."[280] As discussed above, the agencies recently issued a final rule addressing the issue of California's authority. NEPA does not require NHTSA to include action alternatives that cannot be lawfully realized.

International Mosiac~~, a blog with participants who are otherwise anonymous,~~ commented that NHTSA's DEIS "is fatally flawed…because it does not consider any market-based alternatives (e.g., a 'cap and trade' type option)."[281] While EPCA/EISA does include very specific provisions regarding trading of CAFE compliance credits, the statute provides no authority for a broad-based cap-and-trade program involving other sectors. Similarly, Michalek, *et al.* wrote that "a more economically efficient approach of, taxing emissions and fuel

Commented [A105]: CHANGE AS SHOWN: As noted elsewhere, commenting on the individuals or membership of organizations gives the appearance of bias, and is not necessary for responding on substance.

[278] Ron Lindsay, EPA-HQ-OAR-2018-0283-1414, at 6
[279] SCAQMD, NHTSA-2018-0067-5666, at 1-2; Shyam Shukla, NHTSA-2018-0067-5793, at 1-2.
[280] NCAT, NHTSA-2018-0067-11969, at 64; NCDEQ, NHTSA-2018-0067-12025, at 38; CBD *et al.*, NHTSA-2018-0067-12123, Attachment 1, at 18.
[281] International Mosaic, NHTSA-2018-0067-11154, at 1-2

consumption at socially appropriate levels would allow households to determine whether to reduce fuel consumption and emissions by driving less, by buying a vehicle with more fuel saving technologies, or by buying a smaller vehicle – or, alternatively, not to reduce fuel consumption and emissions at all but rather pay a cost based on the damages they cause. Forcing improvements only through one mechanism (fuel-saving technologies) increases the cost of achieving these outcomes."[282] ~~While some economists would agree with these comments, Congress has provided no clear authority for NHTSA or EPA to implement either an emissions tax or a broad-based cap-and-trade program in which motor vehicles could participate.~~ An emissions tax or broad-based cap-and-trade program extending beyond the existing light duty vehicle standards is well beyond the scope of this rulemaking.

Commented [A106]: CHANGE AS SHOWN: EPA believes it is unnecessary to discuss economists' views on cap and trade, or to speculate on Congress' intent, but rather, simply say these comments are out of scope for this rule.

3. Details of alternatives considered in final rule

a) Alternative 1

Alternative 1 holds the stringency of targets constant and MY 2020 levels through MY 2026.

[282] Michalek, *et al.*, NHTSA-2018-0067-11903, at 13.

Commented [A107]: REVISE: Car CO2 targets appear to be incorrect, less stringent than MY2020 standards.

Table V-8 - Characteristics of Alternative 1 – Passenger Cars

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	48.74	48.74	48.74	48.74	48.74	48.74
b (mpg)	36.47	36.47	36.47	36.47	36.47	36.47
c (gpm per s.f.)	0.000460	0.000460	0.000460	0.000460	0.000460	0.000460
d (gpm)	0.00164	0.00164	0.00164	0.00164	0.00164	0.00164
CO_2 Targets						
a (g/mi)	169	169	169	169	169	169
b (g/mi)	230	230	230	230	230	230
c (g/mi per s.f.)	4.09	4.09	4.09	4.09	4.09	4.09
d (g/mi)	0.8	0.8	0.8	0.8	0.8	0.8

Table V-9 - Characteristics of Alternative 1 – Light Trucks

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	39.11	39.11	39.11	39.11	39.11	39.11
b (mpg)	25.25	25.25	25.25	25.25	25.25	25.25
c (gpm per s.f.)	0.000514	0.000514	0.000514	0.000514	0.000514	0.000514
d (gpm)	0.00449	0.00449	0.00449	0.00449	0.00449	0.00449
e (mpg)	35.41	35.41	35.41	35.41	35.41	35.41
f (mpg)	25.25	25.25	25.25	25.25	25.25	25.25
g (gpm per s.f.)	0.000455	0.000455	0.000455	0.000455	0.000455	0.000455
h (gpm)	0.00960	0.00960	0.00960	0.00960	0.00960	0.00960

CO_2 Targets						
a (g/mi)	210	210	210	210	210	210
b (g/mi)	335	335	335	335	335	335
c (g/mi per s.f.)	4.57	4.57	4.57	4.57	4.57	4.57
d (g/mi)	22.7	22.7	22.7	22.7	22.7	22.7
e (g/mi)	234	234	234	234	234	234
f (g/mi)	335	335	335	335	335	335
g (g/mi per s.f.)	4.04	4.04	4.04	4.04	4.04	4.04
h (g/mi)	68.1	68.1	68.1	68.1	68.1	68.1

b) Alternative 2

Alternative 2 increases the stringency of targets annually during MYs 2021-2026 (on a gallon per mile basis, starting from MY 2020) by 0.5% for passenger cars and 0.5% for light trucks.

Table V-10 - Characteristics of Alternative 2 – Passenger Cars

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	48.99	49.23	49.48	49.73	49.98	50.23
b (mpg)	36.65	36.84	37.02	37.21	37.39	37.58
c (gpm per s.f.)	0.000458	0.000456	0.000453	0.000451	0.000449	0.000447
d (gpm)	0.00163	0.00163	0.00162	0.00161	0.00160	0.00159
CO_2 Targets						
a (g/mi)	168	167	166	165	164	163
b (g/mi)	229	227	226	225	224	223
c (g/mi per s.f.)	4.07	4.05	4.03	4.01	3.99	3.97
d (g/mi)	0.7	0.7	0.6	0.5	0.4	0.4

Table V-11 - Characteristics of Alternative 2 – Light Trucks

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	39.31	39.51	39.70	39.90	40.10	40.31
b (mpg)	25.37	25.50	25.63	25.76	25.89	26.02
c (gpm per s.f.)	0.000511	0.000509	0.000506	0.000504	0.000501	0.000499
d (gpm)	0.00447	0.00445	0.00443	0.00440	0.00438	0.00436
e (mpg)	35.41	35.41	35.41	35.41	35.41	35.41
f (mpg)	25.25	25.25	25.25	25.25	25.25	25.25

Commented [A108]: **REVISE:** Car CO2 targets appear to be incorrect, MY2021 less stringent than MY2020.

g (gpm per s.f.)	0.000455	0.000455	0.000455	0.000455	0.000455	0.000455
h (gpm)	0.00960	0.00960	0.00960	0.00960	0.00960	0.00960
CO_2 Targets						
a (g/mi)	209	208	207	206	204	203
b (g/mi)	333	331	330	328	326	324
c (g/mi per s.f.)	4.55	4.52	4.50	4.48	4.45	4.43
d (g/mi)	22.5	22.3	22.1	21.9	21.7	21.6
e (g/mi)	234	234	234	234	234	234
f (g/mi)	335	335	335	335	335	335
g (g/mi per s.f.)	4.04	4.04	4.04	4.04	4.04	4.04
h (g/mi)	68.1	68.1	68.1	68.1	68.1	68.1

c) Alternative 3

Alternative 3, the final standards promulgated today, increases the stringency of targets annually during MYs 2021-2026 (on a gallon per mile basis, starting from MY 2020) by 1.5% for passenger cars and 1.5% for light trucks.

Commented [A109]: CHANGE AS SHOWN: Values corrected to represent 1.5% yoy improvement.

Table V-12 - Characteristics of Alternative 3 (Final Standards) – Passenger Cars

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	49.48	50.24	51.00	51.78	52.57	53.37
b (mpg)	37.02	37.59	38.16	38.74	39.33	39.93
c (gpm per s.f.)	0.000453	0.000447	0.000440	0.000433	0.000427	0.000420
d (gpm)	0.00162	0.00159	0.00157	0.00155	0.00152	0.00150
CO_2 Targets						
a (g/mi)	161.8~~166~~	159.0~~163~~	156.4~~160~~	153.7~~158~~	151.2~~155~~	148.6~~153~~
b (g/mi)	220.9~~226~~	217.3~~223~~	213.7~~219~~	210.2~~216~~	206.8~~212~~	203.4~~209~~
c (g/mi per s.f.)	3.94~~4.03~~	3.88~~3.97~~	3.82~~3.91~~	3.77~~3.85~~	3.71~~3.79~~	3.65~~3.74~~
d (g/mi)	0.2~~0.6~~	-0.1~~0.4~~	-0.4~~0.2~~	-0.6~~0.1~~	-0.9~~0.3~~	-1.2~~0.5~~

Table V-13 - Characteristics of Alternative 3 (Final Standards) – Light Trucks

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	39.71	40.31	40.93	41.55	42.18	42.82
b (mpg)	25.63	26.02	26.42	26.82	27.23	27.64
c (gpm per s.f.)	0.000506	0.000499	0.000491	0.000484	0.000477	0.000469
d (gpm)	0.00443	0.00436	0.00429	0.00423	0.00417	0.00410
e (mpg)	35.41	35.41	35.41	35.41	35.41	35.41
f (mpg)	25.25	25.25	25.25	25.25	25.25	25.25

g (gpm per s.f.)	0.000455	0.000455	0.000455	0.000455	0.000455	0.000455
h (gpm)	0.00960	0.00960	0.00960	0.00960	0.00960	0.00960
CO_2 Targets						
a (g/mi)	206.6~~207~~	203.1~~203~~	199.7~~200~~	196.3~~197~~	193.0~~193~~	189.8~~190~~
b (g/mi)	329.7~~330~~	324.4~~324~~	319.2~~319~~	314.0~~314~~	308.9~~309~~	303.9~~304~~
c (g/mi per s.f.)	4.51~~4.50~~	4.44~~4.43~~	4.38~~4.37~~	4.31~~4.30~~	4.25~~4.24~~	4.18~~4.17~~
d (g/mi)	21.7~~22.4~~	21.0~~21.5~~	20.3~~21.0~~	19.6~~20.4~~	19.0~~19.8~~	18.3~~19.3~~
e (g/mi)	234	234	234	234	234	234
f (g/mi)	335	335	335	335	335	335
g (g/mi per s.f.)	4.04	4.04	4.04	4.04	4.04	4.04
h (g/mi)	68.1	68.1	68.1	68.1	68.1	68.1

d) Alternative 4

Alternative 4 increases the stringency of targets annually during MYs 2021-2026 (on a gallon per mile basis, starting from MY 2020) by 1.0% for passenger cars and 2.0% for light trucks.

Table V-14 - Characteristics of Alternative 4 – Passenger Cars

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	49.23	49.73	50.23	50.74	51.25	51.77
b (mpg)	36.84	37.21	37.58	37.96	38.35	38.73
c (gpm per s.f.)	0.000456	0.000451	0.000447	0.000442	0.000438	0.000433
d (gpm)	0.00163	0.00161	0.00159	0.00158	0.00156	0.00155
CO_2 Targets						
a (g/mi)	167	165	163	161	160	158
b (g/mi)	227	225	223	220	218	216
c (g/mi per s.f.)	4.05	4.01	3.97	3.93	3.89	3.85
d (g/mi)	0.7	0.5	0.4	0.2	0.1	-0.1

Commented [A110]: **REVISE:** Car CO2 targets appear to be incorrect, MY2021 less stringent than MY2020.

Table V-15 - Characteristics of Alternative 4 – Light Trucks

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	39.91	40.72	41.56	42.40	43.27	44.15
b (mpg)	25.76	26.29	26.82	27.37	27.93	28.50
c (gpm per s.f.)	0.000504	0.000494	0.000484	0.000474	0.000465	0.000455
d (gpm)	0.00440	0.00432	0.00423	0.00415	0.00406	0.00398
e (mpg)	35.41	35.41	35.41	35.41	35.41	35.41
f (mpg)	25.25	25.25	25.25	25.25	25.25	25.25

g (gpm per s.f.)	0.000455	0.000455	0.000455	0.000455	0.000455	0.000455
h (gpm)	0.00960	0.00960	0.00960	0.00960	0.00960	0.00960
CO_2 Targets						
a (g/mi)	205	201	197	192	188	184
b (g/mi)	328	321	314	307	301	295
c (g/mi per s.f.)	4.48	4.39	4.30	4.21	4.13	4.05
d (g/mi)	21.9	21.2	20.4	19.6	18.9	18.2
e (g/mi)	234	234	234	234	234	234
f (g/mi)	335	335	335	335	335	335
g (g/mi per s.f.)	4.04	4.04	4.04	4.04	4.04	4.04
h (g/mi)	68.1	68.1	68.1	68.1	68.1	68.1

e) Alternative 5

Alternative 5 increases the stringency of targets annually during MYs 2022-2026 (on a gallon per mile basis, starting from MY 2021) by 1.0% for passenger cars and 2.0% for light trucks.

Table V-16 - Characteristics of Alternative 5 – Passenger Cars

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	50.83	51.34	51.86	52.39	52.92	53.45
b (mpg)	38.02	38.40	38.79	39.18	39.58	39.98
c (gpm per s.f.)	0.000442	0.000437	0.000433	0.000429	0.000425	0.000420
d (gpm)	0.00155	0.00154	0.00152	0.00151	0.00149	0.00148
CO_2 Targets						
a (g/mi)	161	159	158	156	154	152
b (g/mi)	220	218	215	213	211	208
c (g/mi per s.f.)	3.93	3.89	3.85	3.81	3.77	3.73
d (g/mi)	0.0	-0.1	-0.3	-0.4	-0.5	-0.7

Commented [A111]: REVISE: Car CO2 targets appear to be incorrect, MY2021 targets do not match current regs.

Table V-17 - Characteristics of Alternative 5 – Light Trucks

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	41.80	42.65	43.52	44.41	45.32	46.24
b (mpg)	25.25	25.76	26.29	26.82	27.37	27.93
c (gpm per s.f.)	0.000482	0.000472	0.000463	0.000454	0.000445	0.000436
d (gpm)	0.00416	0.00408	0.00400	0.00392	0.00384	0.00376
e (mpg)	35.41	35.41	35.41	35.41	35.41	35.41
f (mpg)	25.25	25.25	25.25	25.25	25.25	25.25

g (gpm per s.f.)	0.000455	0.000455	0.000455	0.000455	0.000455	0.000455
h (gpm)	0.00960	0.00960	0.00960	0.00960	0.00960	0.00960
CO_2 Targets						
a (g/mi)	195	191	187	183	179	175
b (g/mi)	335	328	321	314	307	301
c (g/mi per s.f.)	4.28	4.20	4.11	4.03	3.95	3.87
d (g/mi)	19.8	19.1	18.3	17.6	16.9	16.2
e (g/mi)	234	234	234	234	234	234
f (g/mi)	335	335	335	335	335	335
g (g/mi per s.f.)	4.04	4.04	4.04	4.04	4.04	4.04
h (g/mi)	68.1	68.1	68.1	68.1	68.1	68.1

f) Alternative 6

Alternative 6 increases the stringency of targets annually during MYs 2021-2026 (on a gallon per mile basis, starting from MY 2020) by 2.0% for passenger cars and 3.0% for light trucks.

Table V-18 - Characteristics of Alternative 6 – Passenger Cars

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	49.74	50.75	51.79	52.84	53.92	55.02
b (mpg)	37.21	37.97	38.75	39.54	40.34	41.17
c (gpm per s.f.)	0.000451	0.000442	0.000433	0.000425	0.000416	0.000408
d (gpm)	0.00161	0.00158	0.00155	0.00152	0.00149	0.00146
CO_2 Targets						
a (g/mi)	165	161	158	154	151	148
b (g/mi)	225	220	216	211	206	202
c (g/mi per s.f.)	4.01	3.93	3.85	3.77	3.70	3.62
d (g/mi)	0.5	0.2	-0.1	-0.3	-0.6	-0.9

Commented [A112]: REVISE: Car CO2 targets appear to be incorrect, too high. MY2021 only slightly more stringent than MY2020 tagets.

Table V-19 - Characteristics of Alternative 6 – Light Trucks

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	40.32	41.57	42.85	44.18	45.55	46.95
b (mpg)	26.03	26.83	27.66	28.52	29.40	30.31
c (gpm per s.f.)	0.000499	0.000484	0.000469	0.000455	0.000441	0.000428
d (gpm)	0.00436	0.00423	0.00410	0.00398	0.00386	0.00374
e (mpg)	35.41	35.41	35.41	35.41	35.41	35.41
f (mpg)	25.25	25.25	25.25	25.25	25.25	25.25

g (gpm per s.f.)	0.000455	0.000455	0.000455	0.000455	0.000455	0.000455
h (gpm)	0.00960	0.00960	0.00960	0.00960	0.00960	0.00960
CO_2 Targets						
a (g/mi)	203	197	190	184	178	172
b (g/mi)	324	314	304	294	285	276
c (g/mi per s.f.)	4.43	4.30	4.17	4.04	3.92	3.80
d (g/mi)	21.5	20.4	19.3	18.2	17.1	16.1
e (g/mi)	234	234	234	234	234	234
f (g/mi)	335	335	335	335	335	335
g (g/mi per s.f.)	4.04	4.04	4.04	4.04	4.04	4.04
h (g/mi)	68.1	68.1	68.1	68.1	68.1	68.1

g) Alternative 7

Alternative 7 increases the stringency of targets annually during MYs 2022-2026 (on a gallon per mile basis, starting from MY 2021) by 2.0% for passenger cars and 3.0% for light trucks.

Table V-20 - Characteristics of Alternative 7 – Passenger Cars

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	50.83	51.87	52.93	54.01	55.11	56.23
b (mpg)	38.02	38.80	39.59	40.40	41.22	42.06
c (gpm per s.f.)	0.000442	0.000433	0.000424	0.000416	0.000408	0.000399
d (gpm)	0.00155	0.00152	0.00149	0.00146	0.00143	0.00141
CO_2 Targets						
a (g/mi)	161	158	154	151	147	144
b (g/mi)	220	215	211	206	202	197
c (g/mi per s.f.)	3.93	3.85	3.77	3.70	3.62	3.55
d (g/mi)	0.0	-0.3	-0.5	-0.8	-1.1	-1.3

Commented [A113]: **REVISE:** Car CO2 targets appear to be incorrect. MY2021 and MY2022 targets do not match current regs.

Table V-21 - Characteristics of Alternative 7 – Light Trucks

	2021	2022	2023	2024	2025	2026
Fuel Economy Targets						
a (mpg)	41.80	43.09	44.42	45.80	47.21	48.67
b (mpg)	25.25	26.03	26.83	27.66	28.52	29.40
c (gpm per s.f.)	0.000482	0.000468	0.000453	0.000440	0.000427	0.000414
d (gpm)	0.00416	0.00404	0.00392	0.00380	0.00369	0.00358
e (mpg)	35.41	35.41	35.41	35.41	35.41	35.41
f (mpg)	25.25	25.25	25.25	25.25	25.25	25.25

Commented [A114]: **REVISE:** Light truck standards appear to be incorrect. MY2022 targets do not match current regs

g (gpm per s.f.)	0.000455	0.000455	0.000455	0.000455	0.000455	0.000455
h (gpm)	0.00960	0.00960	0.00960	0.00960	0.00960	0.00960
CO_2 Targets						
a (g/mi)	195	189	183	177	171	165
b (g/mi)	335	324	314	304	294	285
c (g/mi per s.f.)	4.28	4.15	4.03	3.91	3.79	3.68
d (g/mi)	19.8	18.7	17.6	16.6	15.6	14.6
e (g/mi)	234	234	234	234	234	234
f (g/mi)	335	335	335	335	335	335
g (g/mi per s.f.)	4.04	4.04	4.04	4.04	4.04	4.04
h (g/mi)	68.1	68.1	68.1	68.1	68.1	68.1

VI. Analytical Approach as Applied to Regulatory Alternatives

A. Overview of Methods

Like analyses accompanying the NPRM and past CAFE and CAFE/CO_2 rulemakings, the analysis supporting today's notice spans a range of technical topics, uses a range of different types of data and estimates, and applies several different types of computer models. The purpose of the analysis is not to determine the standards, but rather to provide information for consideration in doing so. The analysis aims to answer the question "what impacts might each of these regulatory alternatives have?"

Over time, NHTSA's and, more recently, NHTSA's and EPA's analyses have expanded to address an increasingly wide range of types of impacts. Today's analysis involves, among other things, estimating how the application of various combinations of technologies could impact vehicles' costs and fuel economy levels (and CO_2 emission rates), estimating how vehicle manufacturers might respond to standards by adding fuel-saving technologies to new vehicles, estimating how changes in new vehicles might impact vehicle sales and operation, and estimating how the combination of these changes might impact national-scale energy

Commented [A115]: REVISE: This section contains numerous factually incorrect and unnecessary statements about EPA's modeling work, particularly, but not exclusively the ALPHA and LPM models. EPA's overall recommendation is that this section remain focused solely on why the use of the Autonomie model is appropriate for this FRM, and entirely avoid any attempt by NHTSA to characterize EPA's work.

We have attempted to flag for deletion or revision any text that contains these unnecessary statements about EPA's work, but we may have missed some statements, so an additional review after revisions are made will likely be necessary.

consumption, emissions, highway safety, and public health. In addition, the EIS accompanying today's notice addresses impacts on air quality and climate. The analysis of these factors informs and supports both NHTSA's application of the statutory requirements governing the setting of "maximum feasible" fuel-economy standards under EPCA, including, among others, technological feasibility and economic practicability, and EPA's application of the ~~CAA~~ statutory requirements governing the setting and revision of ~~for tailpipe~~ emissions standards under section 202(a) of the CAA, including technological feasibility, compliance costs, and lead-time.

Commented [A116]: CHANGE AS SHOWN: EPA is correcting references to CAA authority.

Supporting today's analysis, the agencies have brought to bear a variety of different types of data, a few examples of which include fuel economy compliance reports, historical sales and average characteristics of light-duty vehicles, historical economic and demographic measures, historical travel demand and energy prices and consumption, and historical measures of highway safety. Also supporting today's analysis, the agencies have applied several different types of estimates, a few examples of which include projections of the future cost of different fuel-saving technologies, projections of future GDP and the number of households, estimates of the "gap" between "laboratory" and on-road fuel economy, and estimates of the social cost of CO_2 emissions and petroleum "price shocks."

With a view toward transparency, repeatability, and efficiency, the agencies have used a variety of computer models to conduct the vast majority of today's analysis. For example, the agencies have applied DOE/EIA's National Energy Modeling System (NEMS) to estimate future energy prices, EPA's MOVES model to estimate tailpipe emission rates for ozone precursors and other criteria pollutants, DOE/Argonne's GREET model to estimate emission rates for "upstream" processes (*e.g.*, petroleum refining), and DOE/Argonne's Autonomie simulation tool to estimate the fuel consumption impacts of different potential combinations of fuel-saving technology. In addition, the EIS accompanying today's notice applies photochemical models to estimate air quality impacts, and applies climate models to estimate climate impacts of overall emissions changes.

Use of these different types of data, estimates, and models is discussed further below in the most closely relevant sections. For example, the agencies' use of NEMS is discussed below in the portion of Section VI that addresses the macroeconomic context, which includes fuel prices, and the agencies use of Autonomie is discussed in the portion of Section VI that addresses the agencies' approach to estimating the effectiveness of various technologies (in reducing fuel consumption and CO_2 emissions).

Providing an integrated means to estimate both vehicle manufacturers' potential responses to CAFE or CO_2 standards and, in turn, many of the different potential direct results (*e.g.*, changes in new vehicle costs) and indirect impacts (*e.g.*, changes in rates of fleet turnover) of those responses, the CAFE Model plays a central role in the agencies' analysis supporting today's notice. The agencies used the specific models mentioned above to develop inputs to the CAFE model, such as fuel prices and emission factors. Outputs from the CAFE Model are discussed in Sections VII and VIII of today's notice, and in the accompanying RIA. The EIS accompanying today's notice makes use of the CAFE Model's estimates of changes in total emissions from light-duty vehicles, as well as corresponding changes in upstream emissions.

These changes in emissions are included in the set of inputs to the models used to estimate air quality and climate impacts.

The remainder of this overview focuses on the CAFE Model. The purpose of this overview is not to provide a comprehensive technical description of the model,[283] but rather to give an overview of the model's functions, to explain some specific aspects not addressed elsewhere in today's notice, and to discuss some model aspects that were the subject of significant public comment. Some model functions and related comments are addressed in other parts of today's notice. For example, the model's handling of Autonomie-based fuel consumption estimates is addressed in the portion of Section VI that discusses the agencies' application of Autonomie. The model documentation accompanying today's notice provides a comprehensive and detailed description of the model's functions, design, inputs, and outputs.[284]

1. Overview of CAFE Model

The basic design of the CAFE Model is as follows: the system first estimates how vehicle manufacturers might respond to a given regulatory scenario, and from that potential compliance solution, the system estimates what impact that response will have on fuel consumption, emissions, and economic externalities. A regulatory scenario involves specification of the form, or shape, of the standards (*e.g.*, flat standards, or linear or logistic attribute-based standards), scope of passenger car and truck regulatory classes, and stringency of the CAFE and CO_2 standards for each model year to be analyzed.

Manufacturer compliance simulation and the ensuing effects estimation, collectively referred to as compliance modeling, encompass numerous subsidiary elements. Compliance simulation begins with a detailed user-provided initial forecast of the vehicle models offered for sale during the simulation period. The compliance simulation then attempts to bring each manufacturer into compliance with the standards defined by the regulatory scenario contained within an input file developed by the user. For example, a regulatory scenario may define CAFE or CO_2 standards that increase in stringency by 4 percent per year for 5 consecutive years.

The model applies various technologies to different vehicle models in each manufacturer's product line to simulate how each manufacturer might make progress toward compliance with the specified standard. Subject to a variety of user-controlled constraints, the model applies technologies based on their relative cost-effectiveness, as determined by several input assumptions regarding the cost and effectiveness of each technology, the cost of compliance (determined by the change in CAFE or CO_2 credits, CAFE-related civil penalties, or value of CO_2 credits, depending on the compliance program being evaluated and the effective-cost mode in use), and the value of avoided fuel expenses. For a given manufacturer, the compliance simulation algorithm applies technologies either until the manufacturer runs out of cost-effective technologies, until the manufacturer exhausts all available technologies, or, if the manufacturer is assumed to be willing to pay civil penalties, until paying civil penalties becomes

[283] Readers seeking such a description are referred to the Model Documentation at [CITE].
[284] [Text Forthcoming]

more cost-effective than increasing vehicle fuel economy. At this stage, the system assigns an incurred technology cost and updated fuel economy to each vehicle model, as well as any civil penalties incurred by each manufacturer. This compliance simulation process is repeated for each model year available during the study period.

This point marks the system's transition between compliance simulation and effects calculations. At the conclusion of the compliance simulation for a given regulatory scenario, the system contains multiple copies of the updated fleet of vehicles corresponding to each model year analyzed. For each model year, the vehicles' attributes, such as fuel types (*e.g.*, diesel, electricity), fuel economy values, and curb weights have all been updated to reflect the application of technologies in response to standards throughout the study period. For each vehicle model in each of the model year specific fleets, the system then estimates the following: lifetime travel, fuel consumption, carbon dioxide and criteria pollutant emissions, the magnitude of various economic externalities related to vehicular travel (*e.g.*, noise), and energy consumption (*e.g.*, the economic costs of short-term increases in petroleum prices). The system then aggregates model-specific results to produce an overall representation of modeling effects for the entire industry.

Different categorization schemes are relevant to different types of effects. For example, while a fully disaggregated fleet is retained for purposes of compliance simulation, vehicles are grouped by type of fuel and regulatory class for the energy, carbon dioxide, criteria pollutant, and safety calculations. Therefore, the system uses model-by-model categorization and accounting when calculating most effects, and aggregates results only as required for efficient reporting.

2. Representation of the Market

As a starting point, the model needs enough information to represent each manufacturer covered by the program. As discussed below in Section VI.B.1, the MY 2017 analysis fleet contains information about each manufacturer's:

- Vehicle models offered for sale—their current (*i.e.*, MY 2017) production volumes, manufacturer suggested retail prices (MSRPs), fuel saving technology content and other attributes (curb weight, drive type, assignment to technology class and regulatory class);
- Production considerations—product cadence of vehicle models (*i.e.*, schedule of model redesigns and "freshenings"), vehicle platform membership, degree of engine and/or transmission sharing (for each model variant) with other vehicles in the fleet; and
- Compliance constraints and flexibilities—preference for full compliance or penalty payment/credit application, willingness to apply additional cost-effective fuel saving technology io excess of regulatory requirements, projected applicable flexible fuel credits, and current credit balance (by model year and regulatory class) in first model year of simulation.

3. Representation of Fuel-Saving Technologies

The modeling system defines technology pathways for grouping and establishing a logical progression of technologies that can be applied to a vehicle. Technologies that share similar characteristics form cohorts that can be represented and interpreted within the CAFE Model as discrete entities. The following Table VI-1Table VI-1 shows the technologies available within the modeling system used for this final rule. Each technology is discussed in detail in Section [Individual Technologies], below. However, an understanding of the technologies considered and how they are defined in the model (*e.g.*, a 6-speed manual transmission is defined as "MT6") is helpful for the following explanation of the compliance simulation and the inputs required for that simulation.

Table VI-1 – CAFE Model Technologies

Technology	Technology Description	Technology	Technology Description
SOHC	Single Overhead Camshaft Engine	CVT	Continuously Variable Transmission
DOHC	Double Overhead Camshaft Engine	CVTL2	CVT, Level 2
EFR	Improved Engine Friction Reduction	EPS	Electric Power Steering
VVT	Variable Valve Timing	IACC	Improved Accessories
VVL	Variable Valve Lift	CONV	Conventional Powertrain (Non-Electric)
SGDI	Stoichiometric Gasoline Direct Injection	SS12V	12V Micro-Hybrid (Stop-Start)
DEAC	Cylinder Deactivation	BISG	Belt Mounted Integrated Starter/Generator
TURBO1	Turbocharging and Downsizing, Level 1 (1.5271 bar)	SHEVP2	P2 Strong Hybrid/Electric Vehicle
TURBO2	Turbocharging and Downsizing, Level 2 (2.0409 bar)	SHEVPS	Power Split Strong Hybrid/Electric Vehicle
CEGR1	Cooled Exhaust Gas Recirculation, Level 1 (2.0409 bar)	P2HCR0	[Special] SHEVP2 with HCR0 Engine
ADEAC	Advanced Cylinder Deactivation	P2HCR1	[Special] SHEVP2 with HCR1 Engine
HCR0	High Compression Ratio Engine, Level 0	P2HCR2	[Special] SHEVP2 with HCR2 Engine
HCR1	High Compression Ratio Engine, Level 1	PHEV20	20-mile Plug-In Hybrid/Electric Vehicle with HCR Engine
HCR2	High Compression Ratio Engine, Level 2	PHEV50	50-mile Plug-In Hybrid/Electric Vehicle with HCR Engine
VCR	Variable Compression Ratio Engine	PHEV20T	20-mile Plug-In Hybrid/Electric Vehicle with Turbo Engine
VTG	Variable Turbo Geometry	PHEV50T	50-mile Plug-In Hybrid/Electric Vehicle with Turbo Engine
VTGE	Variable Turbo Geometry (Electric)	PHEV20H	[Special] PHEV20 with HCR Engine
TURBOD	Turbocharging and Downsizing with DEAC	PHEV50H	[Special] PHEV50 with HCR Engine
TURBOAD	Turbocharging and Downsizing with ADEAC	BEV200	200-mile Electric Vehicle
ADSL	Advanced Diesel	BEV300	300-mile Electric Vehicle
DSLI	Diesel Engine Improvements	FCV	Fuel Cell Vehicle
DSLIAD	Diesel Engine Improvements with ADEAC	LDB	Low Drag Brakes
CNG	Compressed Natural Gas Engine	SAX	Secondary Axle Disconnect

MT5	5-Speed Manual Transmission	ROLL0	Baseline Tires
MT6	6-Speed Manual Transmission	ROLL10	Low Rolling Resistance Tires, Level 1 (10% Reduction)
MT7	7-Speed Manual Transmission	ROLL20	Low Rolling Resistance Tires, Level 2 (20% Reduction)
AT5	5-Speed Automatic Transmission	AERO0	Baseline Aero
AT6	6-Speed Automatic Transmission	AERO5	Aero Drag Reduction, Level 1 (10% Reduction)
AT6L2	6-Speed Automatic Transmission, Level 2	AERO10	Aero Drag Reduction, Level 1 (10% Reduction)
AT7L2	7-Speed Automatic Transmission, Level 2	AERO15	Aero Drag Reduction, Level 1 (10% Reduction)
AT8	8-Speed Automatic Transmission	AERO20	Aero Drag Reduction, Level 2 (20% Reduction)
AT8L2	8-Speed Automatic Transmission, Level 2	MR0	Baseline Mass
AT8L3	8-Speed Automatic Transmission, Level 3	MR1	Mass Reduction, Level 1 (5% Reduction in Glider Weight)
AT9L2	9-Speed Automatic Transmission, Level 2	MR2	Mass Reduction, Level 2 (7.5% Reduction in Glider Weight)
AT10L2	10-Speed Automatic Transmission, Level 2	MR3	Mass Reduction, Level 3 (10% Reduction in Glider Weight)
AT10L3	10-Speed Automatic Transmission, Level 3	MR4	Mass Reduction, Level 4 (15% Reduction in Glider Weight)
DCT6	6-Speed Dual Clutch Transmission	MR5	Mass Reduction, Level 5 (20% Reduction in Glider Weight)
DCT8	8-Speed Dual Clutch Transmission	MR6	Mass Reduction, Level 6 (28.2% Reduction in Glider Weight)

These entities are then laid out into pathways (or paths), which the system uses to define relations of mutual exclusivity between conflicting sets of technologies. For example, as presented in the next section, technologies on the Turbo Engine path are incompatible with those on the HCR Engine or the Diesel Engine paths. As such, whenever a vehicle uses a technology from one pathway (*e.g.*, turbo), the modeling system immediately disables the incompatible technologies from one or more of the other pathways (*e.g.*, HCR and diesel).

In addition, each path designates the direction in which vehicles are allowed to advance as the modeling system evaluates specific technologies for application. Enforcing this directionality within the model ensures that a vehicle that uses a more advanced or more efficient technology (*e.g.*, AT8) is not allowed to "downgrade" to a less efficient option (*e.g.*, AT5). Visually, as portrayed in the charts in the sections that follow, this is represented by an arrow leading from a preceding technology to a succeeding one, where vehicles begin at the root of each path, and traverse to each successor technology in the direction of the arrows.

The modeling system incorporates twenty technology pathways for evaluation as shown below. Similar to individual technologies, each path carries an intrinsic application level that denotes the scope of applicability of all technologies present within that path, and whether the pathway is evaluated on one vehicle at a time, or on a collection of vehicles that share a common platform, engine, or transmission.

Table VI-2 - Technology Pathways

Technology Pathway	Application Level
Engine Configuration Path	Engine
Engine Improvements Path	Engine
Basic Engine Path	Engine
Turbo Engine Path	Engine
Advanced Cylinder Deactivation (ADEAC) Engine Path	Engine
High Compression Ratio (HCR) Engine Path	Engine
Variable Compression Ratio (VCR) Engine Path	Engine
Variable Turbo Geometry (VTG) Engine Path	Engine
Advanced Turbo Engine Path	Engine
Diesel Engine Path	Engine
Alternative Fuel Engine Path	Engine
Manual Transmission Path	Transmission
Automatic Transmission Path	Transmission
Electric Improvements Path	Vehicle
Electrification Path	Vehicle
Hybrid/Electric Path	Vehicle
Dynamic Load Reduction (DLR) Path	Vehicle
Low Rolling Resistance Tires (ROLL) Path	Vehicle
Aerodynamic Improvements (AERO) Path	Vehicle
Mass Reduction (MR) Path	Platform

Even though technology pathways outline a logical progression between related technologies, all technologies available to the system are evaluated concurrently and independently of each other. Once all technologies have been examined, the model selects a solution deemed to be most cost-effective for application on a vehicle. If the modeling system applies a technology that resides later in the pathway, it will subsequently disable all preceding technologies from further consideration to prevent a vehicle from potentially downgrading to a less advanced option. Consequently, the system skips any technology that is already present on a vehicle (either those that were available on a vehicle from the input fleet or those that were previously applied by the model). This "parallel technology" approach, unlike the "parallel path" methodology utilized in the preceding versions of the model, allows the system always to consider the entire set of available technologies instead of foregoing the application of potentially more cost-effective options that happen to reside further down the pathway.[285] This revised approach addresses comments summarized below, and allows the system to analyze all available technology options concurrently and independently of one other without having to first apply one or more "predecessor" technologies. For example, if model inputs are such that a 7-speed transmission is cost-effective, but not as cost-effective as an 8-speed transmission, the revised approach enables the model to skip over the 7-speed transmission entirely, whereas the NPRM version of the model might first apply the 7-speed transmission and then consider whether to proceed immediately to the 8-speed transmission. As such, the model's choices for

[285] Previous versions of the CAFE Model followed a "low-cost" first approach where the system would stop evaluating technologies residing within a given pathway as soon as the first cost-effective option within that path was reached.

evaluation of new technology solutions becomes slightly less restrictive, allowing it immediately to consider and apply more advanced options, and increasing the likelihood that the a globally optimum solution is selected.

Some commenters supported the agencies' use of such pathways in the simulation of manufacturers' potential application of technologies. As one of a dozen examples of CAFE model design elements that lead to the transparent representation of real-world factors, the Alliance highlighted "recognition of the need for manufacturers to follow 'technology' pathways that retain capital and implementation expertise, such as specializing in one type of engine or transmission instead of following an unconstrained optimization that would cause manufacturers to leap to unrelated technologies and show overly optimistic costs and benefits."[286] Similarly, Toyota commented that "the inertia of capital investments and engineering expertise dedicated to one compliance technology or set of technologies makes it unreasonable for manufacturers to immediately switch to another technology path."[287]

Other commenters cited the use of technology pathways as inherently overly restrictive. For example, as an example of "arbitrary model constraints," a coalition of commenters cited the fact the model "prohibit[s] manufacturers from switching vehicle technology pathways."[288] Also, EDF, UCS, and CARB cited the combination of technology pathways, decisionmaking criteria, and model inputs as producing unrealistic results.[289] Regarding the technology pathways, specifically, EDF's consultant argued that the technology paths are not transparent, and cited the potential that specific paths may not necessarily be arranged in progression from least to most cost-effective—that "NHTSA ignores the cost of the technology when developing this list."[290] Relatedly, as EDF's consultant commented:

> [T]he Volpe Model is not designed to look backwards along its technology paths. Thus, the opportunity to recover the expenditure of inefficient technology is missed. NHTSA might argue that a manufacturer will not invest in 10-speed transmissions, for example, and then return to an older design. Whether or not this is true in real life, such a view would put too much stake in the Volpe Model projections. The model simply projects what could be done, not what will be. Anyone examining the progression of technology and noting the reversion of transmission technology could easily modify the model inputs to avoid this. Also, if NHTSA evaluated combinations of technologies prior to entering them in the model piecemeal, it would automatically avoid such apparent problems.[291]

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[286] Alliance, NHTSA-2018-0067-12073, at 9.
[287] Toyota, NHTSA-2018-0067-12098, at 7.
[288] CBD, et al., NHTSA-2018-0067-12057, at 3.
[289] EDF, NHTSA-2018-0067-12108, Appendix A, at 57 *et seq.*; UCS, NHTSA-2018-0067-12039, Appendix, at 25 *et seq.*; Roush Industries, NHTSA-2018-0067-11984, at 5.
[290] EDF, NHTSA-2018-0067-12108, Appendix B, at 69.
[291] Ibid., at 70.

The agencies also received additional public comments on specific paths and specific interactions between paths (*e.g.*, involving engines and hybridization). These comments are addressed below.

The agencies have carefully considered these comments and the approach summarized below reflects some corresponding revision. As mentioned above, the CAFE model now approaches the technology paths in a such way that, faced with two cost-effective technologies on the same path, the model can proceed directly to the more advanced technology if that technology is the more cost effective of the two.

However, the agencies reject assertions that the model's use of technology paths is not transparent. The agencies provided extensive explanatory text, figures, model documentation, and model source code specifically addressing these paths (and other model features). This transparency appears evident in that commenters (sometimes while claiming that a specific feature of the model is not transparent) presented analytical results involving changes to corresponding inputs that required a detailed understanding of that feature's operation.

Regarding comments that the technology paths should be arranged in order of cost-effectiveness, the agencies note that such comments presume, without merit, that costs, fuel consumption impacts, and other inputs (*e.g.*, fuel prices) that logically impact manufacturers' decision-making are not subject to uncertainty. These inputs are all subject to uncertainty, and the CAFE Model's arrangement of technologies into several paths is responsive to these uncertainties. Nevertheless, the agencies maintain that some technologies *do* reflect a higher level of advancement than others (e.g., 10-speed transmissions vs. 5-speed transmissions), and while manufacturers may, in practice, occasionally revert to less advanced technologies, it is appropriate and reasonable to conduct our analysis in a manner that assumes manufacturers will continue to make forward progress. As observed by EDF's consultant's remarks, the CAFE Model "simply projects what could be done, not what will be." While no model, much less any model relying on information that can be made publicly available, can hope to represent precisely each manufacturers' actual detailed constrains related to product development and planning, such constraints are real and important. The agencies agree that the CAFE Model's representation of such constraints—including the Model's use of technology paths—provides a reasonable means of accounting for them.

Commented [A117]: REVISE: (not here, but elsewhere) Flagging this as an appropriate way to reference a commenter, in that does not involve identifying or characterizing the individual members or contractors of a commenting organization.

4. Compliance Simulation

The CAFE model provides a way of estimating how vehicle manufacturers could attempt to comply with a given CAFE standard by adding technology to fleets that the agencies anticipate they will produce in future model years. This exercise constitutes a simulation of manufacturers' decisions regarding compliance with CAFE or CO_2 standards.

This compliance simulation begins with the following inputs: (a) the analysis fleet of vehicles from model year 2017 discussed below in Section VI.B, (b) fuel economy improving technology estimates discussed below in Section VI.C, (c) economic inputs discussed below in Section VI.D, and (d) inputs defining baseline and potential new CAFE or CO_2 standards discussed above in Section V. For each manufacturer, the model applies technologies in both a

logical sequence and a cost-optimizing strategy in order to identify a set of technologies the manufacturer could apply in response to new CAFE or CO_2 standards. The model applies technologies to each of the projected individual vehicles in a manufacturer's fleet, considering the combined effect of regulatory and market incentives while attempting to account for manufacturers' production constraints. Depending on how the model is exercised, it will apply technology until one of the following occurs:

(1) The manufacturer's fleet achieves compliance[292] with the applicable standard and adding additional technology in the current model year would be attractive neither in terms of stand-alone (*i.e.*, absent regulatory need) cost-effectiveness nor in terms of facilitating compliance in future model years;

(2) The manufacturer "exhausts" available technologies;[293] or

(3) For manufacturers assumed to be willing to pay civil penalties (in the CAFE program), the manufacturer reaches the point at which doing so would be more cost-effective (from the manufacturer's perspective) than adding further technology.

The model accounts explicitly for each model year, applying technologies when vehicles are scheduled to be redesigned or freshened and carrying forward technologies between model years once they are applied (until, if applicable, they are superseded by other technologies). The model then uses these simulated manufacturer fleets to generate both a representation of the U.S. auto industry and to modify a representation of the entire light-duty registered vehicle population. From these fleets, the model estimates changes in physical quantities (gallons of fuel, pollutant emissions, traffic fatalities, etc.) and calculates the relative costs and benefits of regulatory alternatives under consideration.

The CAFE model accounts explicitly for each model year, in turn, because manufacturers actually "carry forward" most technologies between model years, tending to concentrate the application of new technology to vehicle redesigns or mid-cycle "freshenings," and design cycles vary widely among maoufacturers and specific products. Comments by manufacturers and model peer reviewers strongly support explicit year-by-year simulation. Year-by-year accounting also enables accounting for credit banking (*i.e.*, carry-forward), as discussed above, and at least four environmental organizations recently submitted comments urging the agencies to consider such credits, citing NHTSA's 2016 results showing impacts of carried-forward

[292] When determining whether compliance has been achieved in the CAFE program, existing CAFE credits that may be carried over from prior model years or transferred between fleets are also used to determine compliance status. For purposes of determining the effect of maximum feasible CAFE standards, however, EPCA prohibits NHTSA from considering these mechanisms for years being considered (though it does so for model years that are already final) and the agency runs the CAFE model without enabling these options. 49 U.S.C. 32902(h)(3).

[293] In a given model year, it is possible that production constraints cause a manufacturer to "run out" of available technology before achieving compliance with standards. This can occur when: (a) an insufficient volume of vehicles are expected to be redesigned, (b) vehicles have moved to the ends of each (relevant) technology pathway, after which no additional options exist, or (c) engineering aspects of available vehicles make available technology inapplicable (*e.g.*, secondary axle disconnect cannot be applied to two-wheel drive vehicles).

credits.[294] Moreover, EPCA/EISA requires that NHTSA make a year-by-year determination of the appropriate level of stringency and then set the standard at that level, while ensuring ratable increases in average fuel economy through MY 2020. The multi-year planning capability, simulation of "market-driven overcompliance," and EPCA credit mechanisms (again, for purposes of modeling the CAFE program) increase the model's ability to simulate manufacturers' real-world behavior, accounting for the fact that manufacturers will seek out compliance paths for several model years at a time, while accommodating the year-by-year requirement. This same multi-year planning structure is used to simulate responses to standards defined in grams CO_2/mile, and utilizing the set of specific credit provisions defined under EPA's program.

After the light-duty rulemaking analysis accompanying the 2012 final rule that finalized NHTSA's standards through MY 2021, NHTSA began work on changes to the CAFE model with the intention of better reflecting constraints of product planning and cadence for which previous analyses did not account. This involves accounting for expected future schedules for redesigning and "freshening" vehicle models, and accounting for the fact that a given engine or transmission is often shared among more than one vehicle model, and a given vehicle production platform often includes more than one vehicle model. These real product planning considerations are explained below.

Like earlier versions, the current CAFE model provides the capability for integrated analysis spanning different regulatory classes, accounting both for standards that apply separately to different classes and for interactions between regulatory classes. Light vehicle CAFE and CO_2 standards are specified separately for passenger cars and light trucks. However, there is considerable sharing between these two regulatory classes, where a single engine, transmission, or platform can appear in both the passenger car and light truck regulatory class. For example, some sport-utility vehicles are offered in 2WD versions (classified as passenger cars for compliance purposes) and 4WD versions (classified as light trucks for compliance purposes). Integrated analysis of manufacturers' passenger car and light truck fleets provides the ability to account for such sharing and reduces the likelihood of finding solutions that could involve introducing impractical and unrealistic levels of complexity in manufacturers' product lines. In addition, integrated fleet analysis provides the ability to simulate the potential that manufacturers could earn CAFE and CO_2 credits by over complying with the standard in one fleet and use those credits toward compliance with the standard in another fleet (*i.e.*, to simulate credit transfers between regulatory classes).[295]

The CAFE model also accounts for EPCA's requirement that compliance be determined separately for fleets of domestic passenger cars and fleets of imported passenger cars. The model accounts for all three CAFE regulatory classes simultaneously (*i.e.*, in an integrated way) yet separately: domestic passenger cars, imported passenger cars, and light trucks. The model

[294] Comment by Environmental Law & Policy Center, Natural Resources Defense Council (NRDC), Public Citizen, and Sierra Club, Docket ID EPA-HQ-OAR-2015-0827-9826, at 28-29.
[295] Note, however, that EPCA prohibits NHTSA from considering the availability of such credit trading when setting maximum feasible fuel economy standards. 49 U.S.C. 32902(h)(3).

further accounts for two related specific statutory requirements specifically involving this distinction between domestic and imported passenger cars. First, EPCA/EISA requires that any given fleet of domestic passenger cars meet a minimum standard, irrespective of any available compliance credits. Second, EPCA/EISA requires compliance with the standards applicable to the domestic passenger car fleet without regard to traded or transferred credits.[296]

However, the CAA ~~provides no direction~~has no such limitations regarding compliance by domestic and imported vehicles; EPA ~~has~~ did not adopt~~ed~~ provisions similar to the aforementioned EPCA/EISA requirements and is not doing so today. Therefore, the CAFE model determines compliance for manufacturers' overall passenger car and light truck fleets for EPA's program.

Commented [A118]: CHANGE AS SHOWN: Corrections to CAA authority references.

Each manufacturer's regulatory requirement represents the production-weighted harmonic mean of their vehicle's targets in each regulated fleet. This means that no individual vehicle has a "standard," merely a target, and each manufacturer is free to identify a compliance strategy that makes the most sense given its unique combination of vehicle models, consumers, and competitive position in the various market segments. As the CAFE model provides flexibility when defining a set of regulatory standards, each manufacturer's requirement is dynamically defined based on the specification of the standards for any simulation and the distribution of footprints within each fleet.

Given this information, the model attempts to apply technology to each manufacturer's fleet in a manner that, given product planning and engineering-related considerations, optimizes the selected cost-related metric. The metric supported by the NPRM version of the model is termed "effective cost." The effective cost captures more than the incremental cost of a given technology; it represents the difference between their incremental cost and the value of fuel savings to a potential buyer over the first 30 months of ownership.[297] In addition to the technology cost and fuel savings, the effective cost also includes the change in fines from applying a given technology and any estimated welfare losses associated with the technology (*e.g.*, earlier versions of the CAFE model simulated low-range electric vehicles that produced a welfare loss to buyers who valued standard operating ranges between re-fueling events). Comments on this metric are discussed below, as are model changes responding to these comments.

Commented [A119]: REVISE: References to fines should clarify this is for CAFE program only.

This construction allows the model to choose technologies that both improve a manufacturer's regulatory compliance position and are most likely to be attractive to its consumers. This also means that different assumptions about future fuel prices will produce different rankings of technologies when the model evaluates available technologies for application. For example, in a high fuel price regime, an expensive but very efficient technology may look attractive to manufacturers because the value of the fuel savings is sufficiently high

[296] 49 U.S.C. 32903(f)(2) and (g)(4).

[297] The length of time over which to value fuel savings in the effective cost calculation is a model input that can be modified by the user. This analysis uses 30 months' worth of fuel savings in the effective cost calculation, using the price of fuel at the time of vehicle purchase.

both to counteract the higher cost of the technology and, implicitly, to satisfy consumer demand to balance price increases with reductions in operating cost.

In general, the model adds technology for several reasons but checks these sequentially. The model then applies any "forced" technologies. Currently, only variable valve timing (VVT) is forced to be applied to vehicles at redesign since it is the root of the engine path and the reference point for all future engine technology applications.[298] The model next applies any inherited technologies that were applied to a leader vehicle on the same vehicle platform and carried forward into future model years where follower vehicles (on the shared system) are freshened or redesigned (and thus eligible to receive the updated version of the shared component). In practice, very few vehicle models enter without VVT, so inheritance is typically the first step in the compliance loop. Next, the model ~~evaluates the manufacturer's compliance status, applying~~ applies all technologies for which the effective cost is negative,~~cost-effective technologies~~ regardless of compliance status ~~(essentially any technology for which the effective cost is negative)~~. Then the model applies expiring overcompliance credits (if allowed to do so under the perspective of either the "unconstrained" or "standard setting" analysis, for CAFE purposes).[299] At this point, the model checks the manufacturer's compliance status ~~again~~. If the manufacturer is ~~still~~ not compliant (and is *unwilling* to pay civil penalties, again for CAFE modeling), the model will add technologies ~~that are not cost-effective~~ until the manufacturer reaches compliance. If the manufacturer exhausts opportunities to comply with the standard by improving fuel economy/reducing emissions (typically due to a limited percentage of its fleet being redesigned in that year), the model will apply banked CAFE or CO_2 credits to offset the remaining deficit. If no credits exist to offset the remaining deficit, the model will reach back in time to alter technology solutions in earlier model years.

Commented [A120]: CHANGE AS SHOWN: Whether or not the model's algorithm checks compliance here, the explanation is inconsistent since it implies that 1) the model applies negative effective cost technologies based on the compliance status in this step, and 2) applies negative effective cost technologies regardless of compliance status.

Commented [A121]: CHANGE AS SHOWN: Apparently, "not cost-effective" is meant to refer to positive effective cost technologies, but useage is confusing here and wouldn't be commonly understood, and anyways the point is redundant since it's stated above that all negative effective cost techs have already been applied.

The CAFE model implements multi-year planning by looking back, rather than forward. When a manufacturer is unable to comply through cost-effective (*i.e.*, producing effective cost values less than zero) technology improvements or credit application in a given year, the model will "reach back" to earlier years and apply the most cost-effective technologies that were not applied at that time and then carry those technologies forward into the future and re-evaluate the manufacturer's compliance position. The model repeats this process until compliance in the current year is achieved, dynamically rebuilding previous model year fleets and carrying them forward into the future, and accumulating CAFE or CO_2 credits from over-compliance with the standard wherever appropriate.

In a given model year, the model determines applicability of each technology to each vehicle platform, model, engine, and transmission. The compliance simulation algorithm begins the process of applying technologies based on the CAFE or CO_2 standards specified during the current model year. This involves repeatedly evaluating the degree of noncompliance, identifying the next "best" technology (ranked by the effective cost discussed earlier) available on each of the parallel technology paths described above and applying the best of these. The

[298] As a practical matter, this affects very few vehicles. More than 95 percent of vehicles in the market file either already have VVT present or have surpassed the basic engine path through the application of hybrids or electric vehicles.

[299] As mentioned above, EPCA prohibits consideration of available credits when setting maximum feasible fuel economy standards. 49 U.S.C. 32902(h)(3).

algorithm combines some of the pathways, evaluating them sequentially instead of in parallel, to ensure appropriate incremental progression of technologies.

The algorithm first finds the best next applicable technology in each of the technology pathways and then selects the best among these. For CAFE purposes, the model applies the technology to the affected vehicles if a manufacturer is either unwilling to pay penalties or if applying the technology is more cost-effective than paying penalties. Afterwards, the algorithm reevaluates the manufacturer's degree of noncompliance and continues application of technology. Once a manufacturer reaches compliance (*i.e.*, the manufacturer would no longer need to pay penalties), the algorithm proceeds to apply any additional technology determined to be cost-effective (as discussed above). Conversely, if a manufacturer is assumed to prefer to pay penalties, the algorithm only applies technology up to the point where doing so is less costly than paying penalties. The algorithm stops applying additional technology to this manufacturer's products once no more cost-effective solutions are encountered. This process is repeated for each manufacturer present in the input fleet. It is then repeated again for each model year. Once all model years have been processed, the compliance simulation algorithm concludes. The process for CO_2 standard compliance simulation is similar, but without the option of penalty payment, such that technologies are applied until compliance (accounting for any modeled application of credits) is achieved. For both CAFE and CO_2 standards, the model also applies any additional (*i.e.*, beyond required for compliance) technology that "pays back" within a specified period (for the NPRM and today's analysis, 30 months).

Commented [A122]: **REVISE:** This is the opposite order of what's described above, in terms of the application of negative effective cost technologies. Maybe a minor point, if the same result is achieved, but there's no reason that the explanation shouldn't be consistent.

Commented [A123]: **REVISE:** Also not consistent with the explanation above, which states that the model stops when compliance is achieved (rather than when it runs out of negative effective cost techs)

Some commenters argued that the CAFE model applies constraints that excessively limit options manufacturers have to add technology, causing the model to overestimate costs to achieve a given level of improvement.[300] Some of these commenters further argued that the agencies should assume greater potential to apply technologies that contribute to compliance by improving air conditioner efficiency or otherwise reducing "off cycle" fuel consumption and CO_2 emissions.[301] Other commenters argued that such constraints, while warranting some refinements, help the model to simulate manufacturers' decision making realistically and to estimate technology effectiveness and costs reasonably.[302, 303]

Some commenters questioned the "effective cost" metric the model uses to decide among available options, claiming that the metric also causes the model to avoid selection of pathways that are not always economically optimal.[304] One of these commenters recommended the agencies modify the effective cost metric for CO_2 compliance by removing the term placing a monetary value on progress toward compliance, and instead dividing the remaining net cost (*i.e.*, the increase in technology costs minus a portion of the fuel outlays expected to be avoided) by the additional CO_2 credits earned.[305] Another of these commenters claimed on one hand, that the

[300] NHTSA-2018-0067-12057, CBD, et. al, p. 3.
[301] NHTSA-2018-0067-11741, ICCT, Attachment 2, p. 4.
[302] NHTSA-2018-0067-12073, Alliance of Automobile Manufacturers, pp. 134-36.
[303] American Honda Motor Co., "Honda Comments on the NPRM and various proposals contained therein - Prepared for NHTSA, EPA and ARB," October 17, 2018, pp. 12-16.
[304] NHTSA-2018-0067-11741, ICCT, Attachment 3, p. 1-62.
[305] NHTSA-2018-0067-12039, UCS, Technical Appendix, pp. 28-32.

effective cost metric "does not include a measurement of the technology's reduction in fuel consumption or CO_2 emissions" and, on the other, that the metric inappropriately places a value on avoided fuel consumption.[306]

One commenter claimed that the model inappropriately allows earned credits (including CO_2 program credits for which EPA has granted a one-time exemption from carry-forward limits) to expire while also showing undue degrees overcompliance with standards, and further proposed that the model be modified to simulate both credit "carry back" (aka "borrowing") and credit trading between manufacturers.[307]

In addition, some commenters indicated that the agencies' analysis (impliedly, its modeling) should account for some States' mandates that manufacturers sell minimum quantities of "Zero Emission Vehicles" (ZEVs).[308, 309]

Regarding the model's representation of engineering and product planning constraints, the agencies maintain that having such constraints produces more realistic potential (as mentioned above, not "predicted") pathways forward from manufacturers' current fleets than would be the case were these constraints removed. For example, while manufacturers' product plans are protected as confidential business information (CBI), some manufacturers' public comments demonstrate year-by-year balancing such as the CAFE model emulates.[310] Also, even manufacturers that have invested in technologies such as hybrid electric powertrains and Atkinson cycle engines have commented that a manufacturers' past investments will constrain the pathways it can practicably take.[311] Therefore, the agencies have retained the model's basic structural constraints, have updated and expanded the model's technology paths (and, as discussed, the model's logic for approaching these paths), and have updated inputs defining the range of manufacturer-, technology-, and product-specific constraints. These updates are discussed below at greater length.

The agencies have also reconsidered opportunities manufacturers may have to expand the application of technologies that contribute to compliance by improving air conditioner efficiency or otherwise reducing "off cycle" fuel consumption and CO_2 emissions, or to earn credit toward CO_2 compliance by using refrigerants with lower global warming potential (GWP) or reducing the potential for refrigerant leaks. The version of the model used for the proposal accommodates inputs that, for each of these adjustments or credits, applies the same value to every model year. The agencies have revised the model to accommodate inputs that specify the degree of adjustment or credit separately for each model year, and have applied inputs that assume manufacturers will increase application of these improvements to the highest levels reported within the industry.

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[306] NHTSA-2018-0067-12108, EDF, Appendix B, p. 67.
[307] NHTSA-2018-0067-12039, UCS, Technical Appendix, pp. 36-40.
[308] NHTSA-2018-0067-12036, Volvo, p. 5.
[309] NHTSA-2018-0067-11813, South Coast AQMD, Attachment 1, p. 4 and EIS comments, p. 9.
[310] *See, e.g.*, FCA, pp. 5-6.
[311] Toyota, Attachment 1, p. 10.

Regarding comments on the effective cost metric the model uses to compare and select among available options to add technology, the agencies have considered changes such as those mentioned above. Given the myriad of factors that manufacturers can actually consider, any weighing to be conducted using publicly-available information will constitute a simplified representation. Nevertheless, within the model's context, it is obvious that any weighing of options should, at a minimum, consider some measure of each option's costs and benefits. Since this aspect of the model involves simulating manufacturers' decisions, it is also clearly appropriate that these costs and benefits be considered from a manufacturer perspective rather than a social perspective.

The effective cost metric used for the NPRM version of the model represents the cost of a given option as the cost to apply a given technology to a given set of vehicles, and represents the benefit of the same option as the extent to which the manufacturer might expect buyers would be willing to pay for fuel economy (as represented by a portion of the projected fuel savings), combined with any reduction in CAFE civil penalties that the manufacturer might ultimately need to pass along to buyers. The reduction in CAFE civil penalties places a value on progress made toward compliance with CAFE standards. ~~The CAA provides no direction regarding~~For CO_2 standards, ~~so~~ the model accepts inputs specifying an analogous basis for valuing changes in the quantity of CO_2 credits earned from (or required by) a manufacturer's fleet. Because each of these three components (technology cost, fuel benefit, and compliance benefit) is expressed in dollars, subtracting benefits from costs produces a net cost, and after dividing net costs by the number of affected vehicles, it is logical to, at each step, select the option that produces the most negative net unit cost. This approach can be interpreted as maximizing net benefits (to the manufacturer).

Commented [A124]: CHANGE AS SHOWN: The CAA reference was not correct, and EPA does not see a need to reference the CAA here, since this is a discussion of what NHTSA did in the model.

As an alternative, the agencies considered a simpler metric that considers only the cost of the option and the extent to which the option increases the quantity of earned credits, and does not require input assumptions regarding how to value progress toward compliance. Such a metric is expressed in dollars per ton or dollars per gallon such that seeking options that produce the smallest (positive) values can be interpreted as maximizing cost effectiveness (of progress toward compliance). However, simply comparing technology costs to corresponding compliance improvements would implicitly assume that manufacturers do not respond at all to fuel prices. This assumption is clearly unrealistic. For example, if diesel fuel costs $5 per gallon and gasoline costs $2 per gallon, manufacturers will be reluctant to respond to stringent CAFE or CO_2 standards by replacing gasoline engines with diesel engines. Manufacturers' comments credibly assert that fuel prices matter, and in the agencies' judgment, simulations of decisions between available options should continue to account for avoided fuel outlays.

On the other hand, while any metric should incorporate some measure of progress toward compliance, it is not obvious that this progress must be expressed in monetary terms. While the CAFE civil penalty provisions provide a logical basis for doing so with respect to CAFE, the recently-introduced (through EISA) option to trade credit between manufacturers adds an alternative basis that is undefined and uncertain, in part because terms of past trades are not known to the agencies. Also, as mentioned above, EPCA/EISA's civil penalty provisions are not applicable to noncompliance with CO_2 standards.

Therefore, for the purpose of selecting among available options to add technology, the agencies consider it reasonable to use the degree of compliance improvement in "raw" (*i.e.*, not monetized) form, and to divide net costs (*i.e.*, technology costs minus a portion of expected avoided fuel outlays) by this improvement. Under a range of side-by-side tests, this change to the effective cost metric most frequently produced lower overall estimates of compliance costs, although with high fuel prices, this change produced results with significantly greater levels of vehicle electrification ~~and significantly greater overall estimates of compliance~~with estimates of higher -technology costs more than offset by the valued portion of avoided fuel outlays.

Commented [A125]: CHANGE AS SHOWN: Include this description of "valued portion of avoided fuel outlays." Otherwise, it's not clear from the text why the model would apply higher tech costs.

The version of the model used for the proposal simulates the potential that, for a given fleet in a given model year, a manufacturer might be able to use credits from an earlier model year or a different fleet. This version of the model did not explicitly simulate the potential that, for a given fleet in a given model year, a manufacturer might be to use credits from a future model year or a different manufacturer. However, the agencies did apply model inputs that reflected assumptions regarding possible trading of credits actually earned prior to model year 2016 (the earliest represented in detail in the agencies' analysis), and the agencies did examine a case (included in the sensitivity analysis) involving hypothetical "perfect" trading of CO_2 credits among manufacturers by treating the industry as a single "manufacturer." Although past versions of the CAFE Model had included code under development with a view toward eventually simulating one or both of these provisions, this code had never proceeded beyond preliminary experimentation, and had never been the focus of peer reviews or application in published analyses.

Nevertheless, the agencies considered expanding the model to simulate credit "carry back" (or "borrowing") and trading (explicitly, rather than in an idealized hypothetical way). The agencies closely examined the corresponding model revisions proposed by UCS and determined that such methods would not produce repeatable results. This is because the approach proposed by UCS "randomly swaps items in list to minimize trading bias."[312]

~~Even if such revisions could be modified to produce non-random results, including credit banking and trading would introduce highly speculative elements into the agencies' analysis. While manufacturers have occasionally indicated plans to carry back credits from future model years, those plans have sometimes backfired when projected credits have failed to materialize, e.g., by misjudging consumer demand for more efficient vehicles. In the agencies' judgment, it would be inappropriate to set standards based on an analysis that relies on the type of borrowing that has been known to fail. To rely also on credit trading during the model years included in the analysis would compound this undue speculation. For example, including credit borrowing and trading throughout the analysis, as some commenters proposed, would lead to an analysis that depends on the potential that, in order to comply with the MY 2022 standard for light trucks, FCA could use credits it expects to be able to buy from another manufacturer in MY 2025. Even if the agencies' analysis had knowledge of and made use of manufacturers' actual product plans, expectations about the ability to borrow others' unearned credits would necessarily be considered risky and unreliable. Within an analysis that, to provide for public disclosure, extrapolates forward many years from the most recent observed fleet, such transactions would add an~~

Commented [A126]: REVISE: The logic of this response is problematic. Because this is a model is a simulation of the future, progressing year-by-year, the same degree of "speculation" exists for both the previous- and subsequent-year's production. (Whereas in the real-world, the previous year's production is known with certainty.) And therefore from the modeler's perspective, there is no difference in "speculation" for carrying-forward, for example MY2027 credits for use in MY2028, or carrying-back MY2028 credits for us in MY2027. In both cases, the model, unlike the real world, "knows" exactly what the sales and available credits are.

In short, in the context of the current CAFE model design, the uncertainty about credit availability in future model years is not a sound justification for considering carry-forward credits, but ignoring carry-back credits.

[312] UCS, NHTSA-2018-0067-12039, Technical Appendix, at 84-87.

~~unreasonable level of speculation. Therefore, the agencies have declined to introduce credit borrowing and trading into the model's logic.~~

The analysis presented in the proposal applied inputs reflecting potential application of credits earned earlier than the first year modeled explicitly. However, as observed by some commenters, those inputs did not fully account for the one-time exemption from the 5-year limit on the extent to which manufacturers may carry forward CO_2 credits. The agencies have updated the analysis fleet to MY 2017 and, in doing so, have updated inputs specifying how credits earned to MY 2017 might be applied. These updates implement a reasonably full accounting of these "legacy" credits, including of the one-time exemption from the credit life limit.

~~As mentioned above, some commenters also indicated that the model is unrealistically "reluctant" to apply credits carried forward from early model years. As explained in the proposal and in the model documentation, the model's application of carried-forward credits is partially controlled by model inputs, which, for the proposal, were set to assume that manufacturers would tend to retain credits as long as possible. This assumption is entirely consistent with manufacturers' past practice and logical in a context wherein the stringency of standards is generally increasing over time. Even though using credits in some model years might seem initially advantageous, doing so means foregoing actual improvements likely to be needed in later model years.~~

Commented [A127]: REVISE: This discussion of credit utilization needs revision, since it does not reflect the information that NHTSA had communicated to EPA in Feb-June 2019 regarding the changes made to the CAFE model to avoid the wasteful expiration of credits.

Regarding the model's treatment of mandates and credits for the sale of ZEVs, as indicated in the model documentation accompanying the proposal, these capabilities were experimental in that version of the model. The reference case analysis for today's notice, like that for the proposal, does not simulate compliance with ZEV mandates.[313]

For the NPRM, the CAFE model was exercised with inputs extending this explicit simulation of technology application through MY 2032, as the agencies anticipated this was sufficiently beyond MY 2026 that nearly all multiyear planning attributable to MY 2026 standards should be accounted for, and any compliance credits carried forward from MY 2026 would have expired. The analysis met this expectation, and the agencies presented analysis of the resultant estimated impacts over the useful lives of vehicles produced prior to MY 2030. The agencies invited comment on all aspects of the analysis, and relevant to this aspect of the analysis—*i.e.*, its perspective and temporal span—EDF stated that that these led the agencies to overstate the proposal's positive impacts on safety, in part because by explicitly representing vehicle model years only through 2032, the agencies had failed to account for the impact of distant model years prices and fuel economy levels on the retention and scrappage of vehicles produced through MY 2029.[314] For example, some vehicles produced in MY 2026 will likely still be on the road during calendar years (CY) 2033-2050 and the rates at which these MY 2026 vehicles will be scrapped during CYs 2033-2050 will be impacted by the prices and fuel economy levels of vehicles produced during MYs 2033-2050. The agencies have addressed this

[313] The agencies note their finalization of the One National Program Final Action, in which EPA partially withdrew a waiver of CAA preemption previously granted to the State of California relating to its ZEV mandate, and NHTSA finalized regulations providing that State ZEV mandates are impliedly and expressly preempted by EPCA. This joint action is available at 84 FR 51310.

[314] EDF, NHTSA-2018-0067-12108, Attachment A at 11 and Attachment B at 11-28.

comment by expanding model inputs to extend the explicit simulation of technology application through MY 2050. Most of these expanded model inputs involve the analysis fleet and inputs defining the cost and availability of various fuel-saving technologies. These inputs are discussed below. The agencies also made minor modifications to the model in order to extend model outputs to cover this wider span and to carry forward each regulatory alternative's standards automatically through the last year to be modeled (*e.g.*, extending standards without change from MY 2032 through MY 2050). The model documentation discusses these minor changes.[315] In addition, although the agencies published detailed model output files documenting all estimated annual impacts through calendar year 2089, the notice and PRIA both emphasized the above-mentioned "model year" perspective, as in past regulatory analyses supporting CAFE ~~and CO_2~~ standards. Recognizing that an alternative "calendar year" perspective is of interest to EDF and, perhaps other stakeholders, the agencies have expanded the presentation of results in today's notice and FRIA by presenting some physical impacts (*e.g.*, fuel consumption and CO_2 emissions) as well as monetized benefits, costs, and net benefits for each of CYs 2017-2050. All of these results appear in the model output files published with today's notice, as do corresponding results for more specific impacts (*e.g.*, year-by-year components of monetized social costs).[316]

Commented [A128]: CHANGE AS SHOWN: Previous GHG analyses have emphasized the "calendar year" perspective, with the "model year" perspective included for completeness.

5. Calculation of Physical Impacts

Once it has completed the simulation of manufacturers' potential application of technology in response to CAFE/CO_2 standards and fuel prices, the CAFE Model calculates impacts of the resultant changes in new vehicle fuel economy levels and prices. This involves several steps.

The model calculates changes in the total quantity of new vehicles sold in each model year as well as the relative shares passenger cars and light trucks comprise of the overall new vehicle market. These agencies received many comments on the estimation of sales impacts, and as discussed below in Section [Sales and Fleet Share], today's analysis applies methods and corresponding estimates that reflect careful consideration of these comments. Related to these calculations, the model now operates in an iterated fashion with a view toward obtaining sales impacts that are balanced with changes in vehicle prices and fuel economy levels. This involves solving for compliance, calculating sales impacts, re-solving for compliance, and repeating these steps as many times as specified in model inputs. For today's analysis, the agencies operated the model with four iterations, as early testing suggested three iterations should be sufficient for fleetwide results to converge between iterations. The model documentation describes the procedures for iteration in detail.

The impacts on outlays for new vehicles occur coincident with the sale of these vehicles so the model can simply calculate and record these for each model year included in the analysis. However, virtually all other impacts result from vehicle operation that extends long after a vehicle is produced. Like other models (including, *e.g.*, NEMS), the CAFE Model includes

[315] The model and documentation are available at https://www.nhtsa.gov/corporate-average-fuel-economy/compliance-and-effects-modeling-system.
[316] Detailed model inputs and outputs are available at https://www.nhtsa.gov/corporate-average-fuel-economy/compliance-and-effects-modeling-system.

procedures (sometimes referred to as "stock models" or as models of fleet turnover) to estimate annual rates at which new vehicles are used and subsequently scrapped. The agencies received many comments on procedures for estimating vehicle scrappage and on procedures for estimating annual quantities of highway travel, accounting for the elasticity of travel demand with respect to per-mile costs for fuel. Below, [Section xxx] discusses these comments and reviews procedures and corresponding estimates that also reflect careful consideration of these comments.

For each vehicle model in each model year, these procedures result in estimates of the number of vehicles remaining in service in each calendar year, as well as the annual mileage accumulation (*i.e.*, vehicle miles traveled, or VMT) in each calendar year. As mentioned above, most of the physical impacts of interest derive from this vehicle operation. Also discussed above, the simulated application of technology results in "initial" and "final" estimates of the cost, fuel type, fuel economy, and fuel share (for, in particular, PHEVs that can run on gasoline or electricity) applicable to each vehicle model in each model year. Together with quantities of travel, and with estimates of the "gap" between "laboratory" and "on-road" fuel economy, these enable calculation of quantities of fuel consumed in each year during the useful life of each vehicle model produced in each model year.[317] The model documentation provides specific procedures and formulas implementing these calculations.

As for the NPRM, the model calculates emissions of CO_2 and other air pollutants, reporting emissions both from vehicle tailpipes and from upstream processes (*e.g.*, petroleum refining) involved in producing and supplying fuels. Section VI.D.3 below reviews methods, models, and estimates used in performing these calculations. The model also calculates impacts on highway safety, accounting for changes in travel demand, changes in vehicle mass, and continued past and expected progress in vehicle safety (through, *e.g.*, the application of new crash avoidance systems). Section VI.D.2 discusses methods, data sources, and estimates involved in estimating safety impacts, comments on the same, and changes included in today's analysis. In response to the NPRM, some comments urged the agencies also to quantify different types of health impacts from changes in air pollution rather than only accounting for such impacts in aggregate estimates of the social costs of air pollution. Considering these comments, the agencies added such calculations to the model, as discussed in Section VI.D.3.

6. Calculation of Benefits and Costs

Having estimated how technologies might be applied going forward, and having estimated the range of resultant physical impacts, the CAFE Model calculates a variety of private and social benefits and costs, reporting these from the consumer, manufacturer, and social perspectives, both in undiscounted and discounted present value form (given inputs specifying the corresponding discount rate and present year). Estimates of regulatory costs are among the direct outputs of the simulation of manufacturers' potential responses to new standards. Other benefits and costs are calculated based on the above-mentioned estimates of travel demand, fuel

[317] As discussed in Section [Text Forthcoming] for today's analysis, the agencies have applied the same estimates of the "on road gap" as applied for the analysis supporting the NPRM. For operation on gasoline, diesel, E85, and CNG, this gap is 20 percent; for electricity and hydrogen, 30 percent.

consumption, emissions, and safety impacts. The agencies received many comments on the NPRM's calculation of benefits and costs, and Section VI.D.1 discusses these comments and presents the methods, data sources, and estimates used in calculating benefits and costs reported here.

7. Structure of Model Inputs and Outputs

All CAFE Model inputs and outputs described above are specified in Microsoft Excel format, and the user can define and edit all inputs to the system. Table VI-3Table VI-3describes (non-exhaustively) which inputs are contained within each input file and Table VI-Table VI- describes which outputs are contained in each output file. This is important for three reasons: (1) each file is discussed throughout the following sections; (2) several commenters conflated aspects of the model with its inputs; and (3) several commenters seemed confused about where to find specific information in the output files. This information was described in detail in the NPRM CAFE Model Documentation, but is reproduced here for quick reference. When specifically referencing the input or output file used for the NPRM or final rule in the following discussion, NPRM or FRM, respectively, will precede the file name.

Table VI-3 – CAFE Model Input Files

Input File	Contents
Market Data (Manufacturers Worksheet)	[text forthcoming]
Market Data (Vehicles Worksheet)	[text forthcoming]
Market Data (Engines Worksheet)	[text forthcoming]
Market Data (Transmissions Worksheet)	[text forthcoming]
Technologies	[text forthcoming]
Technologies_CAFE_SS	[text forthcoming]
Parameters	[text forthcoming]
Scenarios	[text forthcoming]

Table VI-4 – CAFE Model Output Files

Output File	Contents
Technology Utilization Report	[text forthcoming]
Compliance Report	[text forthcoming]
Societal Effects Report	[text forthcoming]
Societal Costs Report	[text forthcoming]
Annual Societal Effects Report	[text forthcoming]
Annual Societal Costs Report	[text forthcoming]
Annual Societal Effects Summary Report	[text forthcoming]
Annual Societal Costs Summary Report	[text forthcoming]
Consumer Costs Report	[text forthcoming]

Vehicles Report	[text forthcoming]

A catalog of the Argonne National Laboratory Autonomie fuel economy technology effectiveness value output files are reproduced in the following Table VI-4Table VI-4 as well.

Table VI-4 – Autonomie Simulation Database Files

Autonomie Simulation Database	Contents
SmallCar	[text forthcoming]
SmallCarPerf	[text forthcoming]
MedCar	[text forthcoming]
MedCarPerf	[text forthcoming]
SmallSUV	[text forthcoming]
SmallSUVPerf	[text forthcoming]
MedSUV	[text forthcoming]
MedSUVPerf	[text forthcoming]
Pickup	[text forthcoming]
PickupHT	[text forthcoming]

B. What Inputs Does the Compliance Analysis Require?

1. Analysis Fleet

[text forthcoming].

2. Flexibilities

a) Treatment of Compliance Credit Provisions

Today's final rule involves a variety of provisions regarding "credits" and other compliance flexibilities. Some recently introduced regulatory provisions allow a manufacturer to earn "credits" that will be counted toward a vehicle's rated CO_2 emissions level, or toward a fleet's rated average CO_2 or CAFE level, without reference to required levels for these average levels of performance. Such flexibilities effectively modify emissions and fuel economy test procedures, or methods for calculating fleets' CAFE and average CO_2 levels. Such provisions are discussed below in sections VI.B.2.c and VI.B.2.d. Other provisions (for CAFE, statutory provisions) allow manufacturers to earn credits by achieving CAFE or average CO_2 levels beyond required levels; these provisions may hence more appropriately be termed "compliance credits."

EPCA has long provided that, by exceeding the CAFE standard applicable to a given fleet in a given model year, a manufacturer may earn corresponding "credits" that the same manufacturer may, within the same regulatory class, apply toward compliance in a different model year. EISA amended these provisions by providing that manufacturers may, subject to specific statutory limitations, transfer compliance credits between regulatory classes, and trade

compliance credits with other manufacturers. T~~hrough t~~he CAA~~. Congress~~ provides EPA with broad standard-setting authority and ~~has provided specific direction regarding criteria pollutant standards, but no direction~~does not contain specific directives regarding ~~either the form of CO_2 standards or~~ CO_2 compliance credits.

Commented [A129]: CHANGE AS SHOWN: Correcting references to CAA authority. Similar edits in paragraph below.

EPCA also specifies that NHTSA may not consider the availability of CAFE credits (for transfer, trade, or direct application) toward compliance with new standards when establishing the standards themselves.[318] Therefore, this analysis, like that presented in the NPRM, considers 2020 to be the last model year in which carried-forward or transferred credits can be applied for the CAFE program. Beginning in model year 2021, today's "standard setting" analysis for NHTSA's program is conducted assuming each fleet must comply with the CAFE standard separately in every model year.

The "unconstrained" perspective acknowledges that these flexibilities exist as part of the program, and, while not considered by NHTSA in setting standards, are nevertheless important to consider when attempting to estimate the real impact of any alternative. Under the "unconstrained" perspective, credits may be earned, transferred, and applied to deficits in the CAFE program throughout the full range of model years in the analysis. The Final Environmental Impact Analysis (FEIS) accompanying today's final rule, like the corresponding Draft EIS analysis, presents results of "unconstrained" modeling. Also, because the CAA ~~provides no direction~~does not contain the constraints found in EPCA regarding consideration of any CO_2 credit provisions, today's analysis, like the NPRM analysis, includes simulation of carried-forward and transferred CO_2 credits in all model years.

Some commenters took issue broadly with this treatment of compliance credits. Michalek and Whitefoot wrote that "we find this requirement problematic because the automakers use these flexibilities as a common means of complying with the regulation, and ignoring them will bias the cost-benefit analysis to overestimate costs."[319]

Counter to the above general claim, the CAFE model *does* provide means to simulate manufacturers' potential application of some compliance credits, and both the analysis of CO_2 standards and the NEPA analysis of CAFE standards *do* make use of this aspect of the model. As discussed above, NHTSA does not have the discretion to consider the credit program—in fact, the agency is prohibited by statute from doing so—in establishing maximum feasible standards. Further, as discussed below, the agencies also continue to find it appropriate for the analysis largely to refrain from simulating two of the mechanisms allowing the use of compliance credits.

The model's approach to simulating compliance decisions accounts for the potential to earn and use CAFE credits as provided by EPCA/EISA. The model similarly accumulates and applies CO_2 credits when simulating compliance with EPA's standards. Like past versions, the current CAFE model can be used to simulate credit carry-forward (a.k.a. banking) between

[318] 49 U.S.C. 32902(h)(3).
[319] Michalek, J. and Whitefoot, K., NHTSA-2018-0067-11903, at 10-11.

model years and transfers between the passenger car and light truck fleets but not credit carry-back (a.k.a. borrowing) from future model years or trading between manufacturers.

Regarding the potential to carry back compliance credits, UCS commented that, although past versions of the CAFE model had "considered this flexibility in its approach to multiyear modeling," NHTSA had, without explanation, "abruptly discontinued support of this method of compliance," such that "manufacturers are generally incentivized to overcomply, regardless of whether carrying forward a deficit to be compensated by later overcompliance would be a more cost-effective method of compliance."[320] Citing the potential that manufacturers could make use of carried back credits in the future, UCS also stated that "NHTSA's decision to constrain it in the model is unreasonable and arbitrary."[321] UCS effectively implies that the agencies should base standards on analysis that presumes manufacturers will take full theoretical advantage of provisions allowing credits to be borrowed.

The agencies have carefully considered these comments, and while EPA's decisions regarding CO_2 standards can consider the potential to carry back compliance credits from later to earlier model years, and NHTSA's "unconstrained" evaluation could also do so, past examples of failed attempts to carry back CAFE credits (e.g., a MY2014 carry back default leading to a civil penalty payment) underscore the riskiness of such "borrowing." Recent evidence indicates manufacturers are disinclined to take such risks,[322] and both agencies find it reasonable and prudent to refrain from attempting to simulate such "borrowing" in rulemaking analysis.

Unlike past versions, the NPRM and current versions of CAFE model provide a basis to specify (in model inputs) CAFE credits available from model years earlier than those being explicitly simulated. For example, with this analysis representing model years 2017-2050 explicitly, credits earned in model year 2012 are made available for use through model year 2017 (given the current five-year limit on carry-forward of credits). The banked credits are specific to both the model year and fleet in which they were earned.

In addition to the above-mentioned comments, UCS also cited as "errors" that "the model does not accurately reflect the one-time exemption from the EPA 5-year credit life for credits earned in the MY 2010-2015 timeframe" and "NHTSA assumes that there will be absolutely no credit trading between manufacturers."

As discussed below, in the course of updating the analysis fleet from MY 2016 to MY 2017, the agencies have updated and expanded the manner in which the model accounts for credits earned prior to MY 2017, including credits earned as early as MY 2009. In order to increase the realism with which the model transitions between the early model year (MYs 2017-2020) and the later years that are the subject of this action, the agencies have accounted for the potential that some manufacturers might trade some of these pre-MY 2017 credits to other manufacturers. However, as with the NPRM, the analysis refrains from simulating the potential

[320] UCS, NHTSA-2018-0067-12039, Technical Appendix, at 44.
[321] UCS, *op. cit.*, at 77.
[322] Section IX, below, reviews data regarding manufacturers' use of CAFE compliance credit mechanism during MYs 2011-2016, and shows that the use of "carry back" credits is, relative to the use of other compliance credit mechanisms, too small to discern.

that manufacturers might continue to trade credits during and beyond the model years covered by today's action. The agencies remain concerned that any realistic simulation of such trading would require assumptions regarding which specific pairs of manufacturers might actually trade compliance credits, and the evidence to date makes it clear that the credit market is far from fully "open." With respect to the FCA comment cited above, ~~the agencies also remain concerned that to set standards based on an analysis that presumes the use of program flexibilities risks making the corresponding actions mandatory~~. Some flexibilities—credit carry-forward (banking) and transfers between fleets in particular—involve little risk, because they are internal to a manufacturer and known in advance. As discussed above, credit carry-back involves significant risk, because it amounts to borrowing against future improvements, standards, and production volume and mix~~—and anticipated market demand for fuel efficient vehicles often fail to materialize~~

Commented [A130]: **REVISE:** EPA does not agree with this response and has in fact modeled program flexibilities such as assumptions on the use of off-cycle credits and air conditioning credits.

The statement about market demand is overblown.

. Similarly, credit trading also involves significant risk, because the ability of manufacturer A to acquire credits from manufacturer B depends not just on manufacturer B actually earning the expected amount of credit, but also on manufacturer B being willing to trade with manufacturer A, and on potential interest by other manufacturers. Manufacturers' compliance plans have already evidenced cases of compliance credit trades that were planned and subsequently aborted, reinforcing the agencies' judgment that, like credit banking, credit trading involves too much risk to be included in an analysis that informs decisions about the stringency of future standards. Nevertheless, recognizing that some manufacturers have actually been trading credits, the agencies have, as in the NPRM, included in the sensitivity analysis a case that simulates "perfect" trading of compliance credits, focusing on CO_2 standards to illustrate the hypothetical maximum potential impact of trading. Section [xxx] of the FRIA summarizes results of this and other cases included in the sensitivity analysis.

As discussed in the CAFE model documentation, the model's default logic attempts to maximize credit carry-forward that is, to "hold on" to credits for as long as possible. If a manufacturer needs to cover a shortfall that occurs when insufficient opportunities exist to add technology in order to achieve compliance with a standard, the model will apply credits. Otherwise the manufacturer carries forward credits until they are about to expire, at which point it will use them before adding technology that is not considered cost-effective. The model attempts to use credits that will expire within the next three years as a means to smooth out technology application over time to avoid both compliance shortfalls and high levels of over-compliance that can result in a surplus of credits. Although it remains impossible precisely to predict manufacturer's actual earning and use of compliance credits, and this aspect of the model may benefit from future refinement as manufacturers and regulators continue to gain experience with these provisions, this approach is generally consistent with manufacturers' observed practices.

NHTSA introduced the CAFE Public Information Center to provide public access to a range of information regarding the CAFE program,[323] including manufacturers' credit balances.

[323] CAFE Public Information Center, http://www.nhtsa.gov/CAFE_PIC/CAFE_PIC_Home.htm (last visited June 22, 2018).

However, there is a data lag in the information presented on the CAFE PIC that may not capture credit actions across the industry for as much as several months. Furthermore, CAFE credits that are traded between manufacturers are adjusted to preserve the gallons saved that each credit represents.[324] The adjustment occurs at the time of application rather than at the time the credits are traded. This means that a manufacturer who has acquired credits through trade, but has not yet applied them, may show a credit balance that is either considerably higher or lower than the real value of the credits when they are applied. For example, a manufacturer that buys 40 million credits from Tesla may show a credit balance in excess of 40 million. However, when those credits are applied, they may be worth only 1/10 as much—making that manufacturer's true credit balance closer to 4 million than 40 million.

For the NPRM, the agencies reviewed then-recent credit balances, estimated the potential that some manufacturers could trade credits, and developed inputs that make carried-forward credits available in each of model years 2011-2015, after subtracting credits assumed to be traded to other manufacturers, adding credits assumed to be acquired from other manufacturers through such trades, and adjusting any traded credits (up or down) to reflect their true value for the fleet and model year into which they were traded.[325] For today's analysis, an additional model year's data was available in mid 2019, and the agencies updated these inputs, as summarized in Table-VI-5Table-VI-5, Table-VI-6Table-VI-6, and Table-VI-7Table-VI-7. While the CAFE model will transfer expiring credits into another fleet (e.g., moving expiring credits from the domestic car credit bank into the light truck fleet), some of these credits were moved into the initial banks to improve the efficiency of application and both to reflect better the projected shortfalls of each manufacturer's regulated fleets and to represent observed behavior. For context, a manufacturer that produces one million vehicles in a given fleet, and experiences a shortfall of 2 mpg, would need 20 million credits, adjusted for fuel savings, to offset the shortfall completely.

Table-VI-5 - Estimated Domestic Car CAFE Credit Banks (in 0.1 mpg), MY 2011-2016

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016
BMW	-	-	-	-	-	-
Daimler	-	-	-	-	1,226,595	221,421
FCA	-	8,338,671	27,797,970	15,753,990	18,927,356	12,908,448
Ford	4,134,214	26,139,750	25,611,410	15,152,856	15,646,131	-
General Motors	-	-	31,604,048	40,857,964	18,314,431	-
Honda	99	100	100	-	13,459,720	34,967,420
Hyundai Kia-H	-	-	-	-	-	
Hyundai Kia-K	-	-	-	-	-	-
JLR	-	-	-	-	-	-
Mazda	15,526	-	-	-	-	-
Mitsubishi	-	-	-	-	-	-

[324] CO_2 credits for EPA's program are denominated in metric tons of CO_2 rather than gram/mile compliance credits and require no adjustment when traded between manufacturers or fleets.

[325] The adjustments, which are based upon the CAFE standard and model year of both the party originally earning the credits and the party applying them, were implemented assuming the credits would be applied to the model year in which they were set to expire. For example, credits traded into a domestic passenger car fleet for MY 2014 were adjusted assuming they would be applied in the domestic passenger car fleet for MY 2019.

Nissan	-	-	18,432,309	44,774,443	42,285,009	31,795,785
Subaru	-	-	-	589,594	1,510,235	-
Tesla	-	-	-	-	-	-
Toyota	137,216	10,291,134	13,474,425	2,181,000	828,440	875,292
Volvo	-	-	-	-	-	-
VWA	-	8,693,832	7,699,790	11,809,524	11,846,008	5,139,096

Table-VI-6 - Estimated Imported Car CAFE Credit Banks (in 0.1 mpg), MY 2011-2016

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016
BMW	-	-	4,121,178	5,343,369	14,068,790	2,418,155
Daimler	-	-	6,644,518	-	-	
FCA	-	13,451,079	5,978,237	6,583,278	7,230,658	-
Ford	-	790,947	-	-	-	-
General Motors	-	-	2,780,629	3,646,294	1,304,196	-
Honda	101	99	100	100	99	1,504,495
Hyundai Kia-H	-	1,747,937	38,683,736	10,185,700	9,658,416	9,072,882
Hyundai Kia-K	10,909,942	7,979,652	11,603,509	-	-	-
JLR	-	-	-	-	-	-
Mazda	5,617,262	7,322,320	7,583,652	15,430,643	13,254,400	14,670,480
Mitsubishi	1,316,570	259,635	65,308	2,002,407	3,121,948	-
Nissan	-	1,035,166	796,821	-	6,022,065	473,522
Subaru	-	-	1,894,165	23,957,705	14,473,258	-
Tesla	-	-	-	-	-	-
Toyota	2,931,153	54,164,765	30,691,277	17,709,001	6,293,119	33,942,542
Volvo	-	-	-	-	-	-
VWA	8,593,792	-	17,295,597	16,260,163	19,538,188	-

Table-VI-7 - Estimated Light Truck CAFE Credit Banks (in 0.1 mpg), MY 2011-2016

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016
BMW	-	-	172,684	235,952	87,135	-
Daimler	-	-	-	-	-	
FCA	-	-	-	6,005,447	19,993,900	-
Ford	-	701,227	11,772,380	10,347,042	7,411,563	-
General Motors	-	-	-	6,276,234	5,574,136	-
Honda	-	100	100	200	100	100
Hyundai Kia-H	286,205	322,525	413,067	759,301	-	-
Hyundai Kia-K	-	-	-	-	-	-
JLR	-	-	-	82,599	335,593	-
Mazda	-	-	1,405,139	-	-	-
Mitsubishi	-	-	-	282,604	1,259,712	1,031,037
Nissan	-	-	-	-	-	-
Subaru	-	-	-	100	158,682	82,840
Tesla	-	-	-	-	-	-
Toyota	-	-	8,664,366	9,082,704	-	-
Volvo	-	-	-	-	-	-
VWA	644,980	77,809	3,862,999	4,067,797	2,393,601	-

In addition to the inclusion of these existing credit banks, the CAFE model also updated its treatment of credits in the rulemaking analysis. EPCA requires that NHTSA set CAFE standards at maximum feasible levels for each model year without consideration of the program's credit mechanisms. However, as recent NHTSA CAFE/EPA tailpipe CO_2 emissions rulemakings have evaluated effects of standards over longer time periods, the early actions taken by manufacturers required more nuanced representation. Accordingly, the CAFE model now provides for a setting to establish a "last year to consider credits." This adjustment is set at the last year for which new standards are not being considered (MY 2020 in this analysis). This allows the model to replicate the practical application of existing credits toward compliance in early years but also to examine the impact of proposed standards based solely on fuel economy improvements in all years for which new standards are being considered.

Regarding the model's simulation of manufacturers' potential earning and application of compliance credits, UCS commented that the model "inexplicably lets credits expire" because "all technologies which pay for themselves within the assumed payback period are applied to all manufacturers, regardless of credit status." UCA also claimed that "NHTSA did not accurately reflect unique attributes of EPA's credit bank," that "credits are not traded between manufacturers," and that "NHTSA does not model credit carryback for compliance."[326] Relatedly, as discussed above, UCS attributes modeling outcomes to the "effective cost" metric used to select from among available fuel-saving technologies.[327] As discussed in Section [xxx], the agencies expect that manufacturers are likely to improve fuel economy voluntarily insofar as doing so "pays back" economically within a short period (30 months), and the agencies note that periods of regulatory stability have, in fact, been marked by CAFE levels exceeding requirements. As discussed above, the agencies have excluded simulation of credit trading (except in MYs prior to those under consideration, aside from an idealized case presented in the sensitivity analysis) and likewise excluded simulation of potential "carryback" provisions. The agencies have excluded modeling these scenarios not just because of the analytical complexities involved (and rejecting, for example, the random number generator analysis suggested by UCS), but also because the agencies agree that the actual provisions regarding trading and borrowing of compliance credits create too much risk to be used in the analysis underlying consideration of standards. However, as discussed above, the agencies have revised the "metric" used to prioritize available options to apply fuel-saving technologies. As discussed below, the agencies have revised model inputs to include the large quantity of "legacy" compliance credits EPA has made available under its CO_2 standards.

The CAFE model has also been modified to include a similar representation of existing credit banks in EPA's CO_2 program. While the life of a CO_2 credit, denominated in metric tons of CO_2, has a five-year life, matching the lifespan of CAFE credits, such credits earned in the early MY 2009-2011 years of the EPA program, may be used through MY 2021.[328] The CAFE model was not modified to allow exceptions to the life-span of compliance credits, and, to reflect

Commented [A131]: CHANGE AS SHOWN: Edits to footnote 328 for clarity - seems awkward to say "in response to comments" from a prior rulemaking

[326] UCS, NHTSA-2018-0067-12039, Technical Appendix, at 35-46.

[327] UCS, NHTSA-2018-0067-12039, Technical Appendix, at 28-30.

[328] In ~~response to comments~~the 2010 rule, EPA placed limits on credits earned in MY 2009, ~~causing them to which~~ expire~~d~~ prior to this rule. However, credits generated in MYs 2010-2011 may be carried forward, or traded, and applied to deficits generated through MY 2021.

EPCA CISA statutory requirements, treated them as if they may be carried forward for no more than five years, so the initial credit banks were modified to anticipate the years in which those credits might be needed. MY 2016 was simulated explicitly in the NPRM analysis to prohibit the inclusion of banked credits in MY 2016 (which could be carried forward from MY 2016 to MY 2021), and thus underestimated the extent to which individual manufacturers, and the industry as a whole, could rely on these early credits to comply with EPA standards between MY 2016 and MY 2021. However, as indicated in the NPRM, the final rule's model inputs updated the analysis fleet's basis to MY 2017, such that these additional banked credits *can* be included. The credit banks with which the simulations in this analysis were conducted are presented in the following tables:

Table-VI-8 - Estimated Passenger Car CO_2 Credit Banks (metric tons), MY 2011-2016

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016
BMW	-	63,382	162,479	1,075,752	-	205,403
Daimler	-	-	573,455	-	2,000,000	-
FCA	-	-	3,000,000	3,000,000	-	-
Ford	-	-	-	-	-	-
General Motors	-	-	-	-	-	-
Honda	-	766,898	179,652	2,271,725	998,495	2,658,425
Hyundai Kia-H	-	-	-	-	-	-
Hyundai Kia-K	-	-	-	-	-	-
JLR	-	-	-	-	-	-
Mazda	-	-	-	-	-	-
Mitsubishi	-	-	-	-	-	-
Nissan	-	-	-	-	-	-
Subaru	-	646,317	1,487,331	3,001,354	3,189,186	5,371,804
Tesla	-	-	-	-	-	-
Toyota	-	-	-	-	-	-
Volvo	-	-	-	0	0	-
VWA	-	-	2,204,413	112,228	-	-

Table-VI-9 - Estimated Light Truck CO_2 Credit Banks (metric tons), MY 2011-2016

Manufacturer	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016
BMW	-	-	-	1,875,752	1,826,118	-
Daimler	-	-	1,600,000	2,300,000	-	2,000,000
FCA	-	5,130,328	6,606,909	8,104,518	8,625,247	13,476,402
Ford	-	546,116	8,431,113	5,048,202	4,238,319	-
General Motors	-	1,251,025	2,861,876	4,423,425	3,251,602	4,500,000
Honda	-	1,470,656	17,848	71,725	1,698,495	1,093,225
Hyundai Kia-H	-	3,535,510	5,613,813	2,231,344	1,916,265	3,789,098
Hyundai Kia-K	-	1,303,379	1,206,280	-	-	2,432,379
JLR	-	703,758	950,094	900,000	900,000	1,200,000
Mazda	-	749,725	786,431	1,547,009	970,540	5,150,625
Mitsubishi	-	211,440	63,036	356,542	350,882	835,211
Nissan	-	845,762	4,538,047	4,930,339	6,150,575	7,133,958
Subaru	-	-	-	-	-	-
Tesla	-	-	-	-	-	-

Toyota	-	13,163,009	5,036,958	2,515,602	6,231,364	9,926,738
Volvo	-	-	-	-	-	-
VWA	-	-	2,800,000	2,000,000	3,000,000	3,000,000

While the CAFE model does not simulate the ability to trade credits between manufacturers, it does simulate the strategic accumulation and application of compliance credits, as well as the ability to transfer credits between fleets to improve the compliance position of a less efficient fleet by leveraging credits earned by a more efficient fleet. The model prefers to hold on to earned compliance credits within a given fleet, carrying them forward into the future to offset potential future deficits. This assumption is consistent with observed strategic manufacturer behavior dating back to 2009.

From 2009 to present, no manufacturer has transferred CAFE credits into a fleet to offset a deficit in the same year in which they were earned. This has occurred with credits acquired from other manufacturers via trade but not with a manufacturer's own credits. Therefore, the current representation of credit transfers between fleets—where the model prefers to transfer expiring, or soon-to-be-expiring credits rather than newly earned credits—is both appropriate and consistent with observed industry behavior.

This may not be the case for CO_2 standards, though it is difficult to be certain at this point. The CO_2 program seeded the industry with a large quantity of early compliance credits (earned in MYs 2009-2011[220]) prior to the existence of formal GHG standards of the EPA program. These eEarly credits for MYs2010 and 2011 do not expire until 2021. So, for manufacturers looking to offset deficits, it is more sensible to use current-year credits that expire in the next five years, rather than draw down the bank of credits that can be used until MY 2021. The first model year for which earned credits outlive the initial bank is MY 2017, for which final compliance actions and deficit resolutions are still pendingmanufacturer GHG performance data has not yet been released. That said, to represent the observed behavior in the CO_2 credit system accurately, the CAFE model allows (and encourages) intra-year transfers between regulated fleets for the purpose of simulating compliance with the CO_2 standards.

Commented [A132]: REVISE: Same footnote appears above, which EPA has edited for clarity. If necessary, could cross-reference rather than repeat same footnote.

Commented [A133]: REVISE: This does not make sense, and the term "current-year credits" is not clear. Manufacturers have an incentive to use credits with the earliest-expiring credits first. "Next five years"as of MY2017-26 goes beyond MY2021.

Commented [A134]: Is this accurate?

b) Off-cycle and A/C Efficiency Adjustments to CAFE and Average CO_2 Levels

In addition to more rigorous accounting of CAFE and CO_2 credits, the model now also accounts for air conditioning efficiency and off-cycle adjustments. NHTSA's program considers those adjustments in a manufacturer's compliance calculation starting in MY 2017, and the NPRM version of the model used the adjustments claimed by each manufacturer in MY 2016 as the starting point for all future years. Because air conditioning efficiency and off-cycle adjustments are not credits in NHTSA's program, but rather adjustments to compliance fuel economy (much like the Flexible Fuel Vehicle adjustments due to phase out in MY 2019), they may be included under either a "standard setting" or "unconstrained" analysis perspective.

[220] In response to public comment, EPA eliminated the possible use of credits earned in MY 2009 for future model years. However, credits earned in MY 2010 and MY 2011 remain available for use.

The manner in which the CAFE model treats the EPA and CAFE A/C efficiency and off-cycle credit programs is similar, but the model also accounts for A/C leakage (which is not part of NHTSA's program). When determining the compliance status of a manufacturer's fleet (in the case of EPA's program, PC and LT are the only fleet distinctions), the CAFE model weighs future compliance actions against the presence of existing (and expiring) CO_2 credits resulting from over-compliance with earlier years' standards, A/C efficiency credits, A/C leakage credits, and off-cycle credits.

Another aspect of credit accounting, implemented in the NPRM version of the CAFE model, involved credits related to the application of off-cycle and A/C efficiency adjustments, which manufacturers earn by taking actions such as special window glazing or using reflective paints that provide fuel economy improvements in real-world operation but do not produce measurable improvements in fuel consumption on the 2-cycle test.

NHTSA's inclusion of off-cycle and A/C efficiency adjustments began in MY 2017, while EPA has collected several years' worth of submissions from manufacturers about off-cycle and A/C efficiency technology deployment. Currently, the level of deployment can vary considerably by manufacturer, with several claiming extensive Fuel Consumption Improvement Values (FCIV) for off-cycle and A/C efficiency technologies, and others almost none. The analysis of alternatives presented here (and in the NPRM) does not attempt to project how future off-cycle and A/C efficiency technology use will evolve or speculate about the potential proliferation of FCIV proposals submitted to the agencies. Rather, this analysis uses the off-cycle credits submitted by each manufacturer for MY 2017 compliance, and, with a few exceptions, carries these forward to future years. Several of the technologies described in Section [xxx] are associated with A/C efficiency and off-cycle FCIVs. In particular, stop-start systems, integrated starter generators, and full hybrids are assumed to generate off-cycle adjustments when applied to vehicles to improve their fuel economy. Similarly, higher levels of aerodynamic improvements are assumed to include active grille shutters on the vehicle, which also qualify for off-cycle FCIVs.

The NPRM analysis assumed that any off-cycle FCIVs that are associated with actions outside of the technologies discussed in Section [xxx] (either chosen from the pre-approved "pick list," or granted in response to individual manufacturer petitions) remained at the levels claimed by manufacturers in MY 2017. Any additional A/C efficiency and off-cycle adjustments that accrued as the result of explicit technology application calculated dynamically in each model year for each alternative. The NPRM version of the CAFE model also represented manufacturers' credits for off-cycle improvements, A/C efficiency improvements, and A/C leakage reduction in terms of values applicable across all model years.

Recognizing that application of these improvements thus far varies considerably among manufacturers, such that some manufacturers have opportunities to earn significantly more of the corresponding adjustments over time, the agencies have expanded the CAFE model's representation of these credits to provide for year-by-year specification of the amounts of each

type of adjustment for each manufacturer, denominated in grams CO_2 per mile,[330] as summarized in the following table:

[330] For estimating their contribution to CAFE compliance, the grams CO_2/mile values in Table VI-10Table VI-1011 are converted to gallons/mile and applied to a manufacturer's 2-cycle CAFE performance. When calculating compliance with EPA's CO_2 program, there is no conversion necessary (as standards are also denominated in grams/mile).

Table VI-10 - Off-Cycle Fuel Economy Adjustments (Exclusive of Technology Tree)[331]

Manufacturer	Passenger Car										Light Truck									
	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
BMW																				
AC Efficiency	4.7	4.7	4.8	4.8	4.9	4.9	5.0	5.0	5.0	5.0	5.5	5.9	6.3	6.7	7.2	7.2	7.2	7.2	7.2	7.2
AC Leakage	13.7	13.7	13.7	13.8	13.8	13.8	13.8	13.8	13.8	13.8	16.8	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle Credits	3.5	4.6	5.6	6.7	7.8	8.9	10.0	10.0	10.0	10.0	6.8	8.1	9.7	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Daimler																				
AC Efficiency	4.9	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	7.1	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
AC Leakage	6.0	7.3	8.6	9.9	11.2	12.5	13.8	13.8	13.8	13.8	6.7	8.4	10.2	11.9	13.7	15.4	17.2	17.2	17.2	17.2
Off-Cycle Credits	1.1	2.6	4.1	5.6	7.0	8.5	10.0	10.0	10.0	10.0	2.4	3.6	4.9	6.2	7.5	8.7	10.0	10.0	10.0	10.0
FCA																				
AC Efficiency	4.2	4.4	4.5	4.6	4.7	4.9	5.0	5.0	5.0	5.0	5.8	6.2	6.6	7.1	7.2	7.2	7.2	7.2	7.2	7.2
AC Leakage	12.5	12.7	12.9	13.1	13.4	13.6	13.8	13.8	13.8	13.8	15.8	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle Credits	3.4	4.5	5.6	6.7	7.8	8.9	10.0	10.0	10.0	10.0	9.8	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Ford																				
AC Efficiency	3.3	3.6	3.9	4.2	4.4	4.7	5.0	5.0	5.0	5.0	5.6	6.0	6.4	6.8	7.2	7.2	7.2	7.2	7.2	7.2
AC Leakage	11.6	12.0	12.4	12.7	13.1	13.4	13.8	13.8	13.8	13.8	12.4	14.9	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle Credits	4.7	5.6	6.5	7.3	8.2	9.1	10.0	10.0	10.0	10.0	9.4	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
General Motors																				
AC Efficiency	3.8	4.0	4.2	4.4	4.6	4.8	5.0	5.0	5.0	5.0	6.5	6.6	6.7	6.8	7.0	7.1	7.2	7.2	7.2	7.2
AC Leakage	9.1	9.9	10.7	11.5	12.2	13.0	13.8	13.8	13.8	13.8	14.7	15.1	15.5	15.9	16.4	16.8	17.2	17.2	17.2	17.2
Off-Cycle Credits	5.3	6.1	6.8	7.6	8.4	9.2	10.0	10.0	10.0	10.0	7.7	9.2	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Honda																				
AC Efficiency	3.0	3.4	3.7	4.0	4.3	4.7	5.0	5.0	5.0	5.0	5.1	5.5	5.9	6.3	6.7	7.2	7.2	7.2	7.2	7.2
AC Leakage	7.4	8.5	9.6	10.6	11.7	12.7	13.8	13.8	13.8	13.8	14.1	16.9	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle Credits	2.0	3.3	4.7	6.0	7.3	8.7	10.0	10.0	10.0	10.0	5.5	6.6	7.9	9.5	10.0	10.0	10.0	10.0	10.0	10.0
Hyundai Kia-H																				
AC Efficiency	3.4	3.7	3.9	4.2	4.5	4.7	5.0	5.0	5.0	5.0	5.4	5.7	6.0	6.3	6.6	6.9	7.2	7.2	7.2	7.2
AC Leakage	3.1	4.8	6.6	8.4	10.2	12.0	13.8	13.8	13.8	13.8	1.6	4.2	6.8	9.4	12.0	14.6	17.2	17.2	17.2	17.2
Off-Cycle Credits	1.5	2.9	4.4	5.8	7.2	8.6	10.0	10.0	10.0	10.0	5.3	6.4	7.7	9.2	10.0	10.0	10.0	10.0	10.0	10.0
Hyundai Kia-K																				
AC Efficiency	3.2	3.5	3.8	4.1	4.4	4.7	5.0	5.0	5.0	5.0	5.2	5.5	5.8	6.2	6.5	6.9	7.2	7.2	7.2	7.2
AC Leakage	7.1	8.2	9.3	10.4	11.6	12.7	13.8	13.8	13.8	13.8	6.7	8.4	10.2	11.9	13.7	15.4	17.2	17.2	17.2	17.2
Off-Cycle Credits	2.0	3.3	4.7	6.0	7.3	8.7	10.0	10.0	10.0	10.0	3.2	4.4	5.5	6.6	7.7	8.9	10.0	10.0	10.0	10.0
JLR																				
AC Efficiency	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
AC Leakage	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle Credits	5.6	6.3	7.1	7.8	8.5	9.3	10.0	10.0	10.0	10.0	8.8	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Mazda																				
AC Efficiency	-	0.8	1.7	2.5	3.3	4.2	5.0	5.0	5.0	5.0	-	1.2	2.4	3.6	4.8	6.0	7.2	7.2	7.2	7.2
AC Leakage	-	2.3	4.6	6.9	9.2	11.5	13.8	13.8	13.8	13.8	-	2.9	5.7	8.6	11.5	14.3	17.2	17.2	17.2	17.2
Off-Cycle Credits	-	1.7	3.3	5.0	6.7	8.3	10.0	10.0	10.0	10.0	-	1.7	3.3	5.0	6.7	8.3	10.0	10.0	10.0	10.0
Mitsubishi																				
AC Efficiency	2.9	3.3	3.6	4.0	4.3	4.7	5.0	5.0	5.0	5.0	2.7	3.5	4.2	5.0	5.7	6.5	7.2	7.2	7.2	7.2
AC Leakage	4.0	5.6	7.3	8.9	10.5	12.2	13.8	13.8	13.8	13.8	6.4	8.2	10.0	11.8	13.6	15.4	17.2	17.2	17.2	17.2
Off-Cycle Credits	2.0	3.4	4.7	6.0	7.3	8.7	10.0	10.0	10.0	10.0	4.5	5.4	6.3	7.2	8.2	9.1	10.0	10.0	10.0	10.0
Nissan																				
AC Efficiency	2.9	3.3	3.6	4.0	4.3	4.7	5.0	5.0	5.0	5.0	2.7	3.5	4.2	5.0	5.7	6.5	7.2	7.2	7.2	7.2
AC Leakage	4.0	5.6	7.3	8.9	10.5	12.2	13.8	13.8	13.8	13.8	6.4	8.2	10.0	11.8	13.6	15.4	17.2	17.2	17.2	17.2
Off-Cycle Credits	2.0	3.4	4.7	6.0	7.3	8.7	10.0	10.0	10.0	10.0	4.5	5.4	6.3	7.2	8.2	9.1	10.0	10.0	10.0	10.0
Subaru																				
AC Efficiency	2.5	2.9	3.4	3.8	4.2	4.6	5.0	5.0	5.0	5.0	4.7	5.1	5.5	5.9	6.4	6.8	7.2	7.2	7.2	7.2
AC Leakage	4.3	5.9	7.4	8.9	10.4	12.0	13.5	13.5	13.5	13.8	7.0	8.7	10.4	12.1	13.8	15.5	17.2	17.2	17.2	17.2
Off-Cycle Credits	0.5	2.1	3.6	5.2	6.8	8.4	10.0	10.0	10.0	10.0	0.5	2.0	3.6	5.2	6.8	8.4	10.0	10.0	10.0	10.0
Tesla																				
AC Efficiency	5.7	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	-	-	-	-	-	-	-	-	-	-
AC Leakage	-										-	-	-	-	-	-	-	-	-	-
Off-Cycle Credits	6.5	7.8	9.4	10.0	10.0	10.0	10.0	10.0	10.0	10.0	-	-	-	-	-	-	-	-	-	-
Toyota																				
AC Efficiency	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.0	5.0	5.0	5.4	5.7	6.0	6.3	6.6	6.9	7.2	7.2	7.2	7.2
AC Leakage	3.2	5.0	6.8	8.5	10.3	12.0	13.8	13.8	13.8	13.8	7.3	9.0	10.6	12.3	13.9	15.6	17.2	17.2	17.2	17.2
Off-Cycle Credits	3.6	4.6	5.7	6.8	7.9	8.9	10.0	10.0	10.0	10.0	7.1	8.6	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Volvo																				
AC Efficiency	4.0	4.2	4.3	4.5	4.7	4.8	5.0	5.0	5.0	5.0	5.8	6.1	6.3	6.5	6.7	7.0	7.2	7.2	7.2	7.2
AC Leakage	5.4	6.8	8.2	9.6	11.0	12.4	13.8	13.8	13.8	13.8	7.0	8.7	10.4	12.1	13.8	15.5	17.2	17.2	17.2	17.2
Off-Cycle Credits	3.4	4.5	5.6	6.7	7.8	8.9	10.0	10.0	10.0	10.0	5.6	6.3	7.0	7.8	8.5	9.3	10.0	10.0	10.0	10.0
VWA																				
AC Efficiency	3.9	4.1	4.3	4.5	4.6	4.8	5.0	5.0	5.0	5.0	6.6	7.1	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
AC Leakage	5.1	6.5	8.0	9.4	10.9	12.3	13.8	13.8	13.8	13.8	6.2	8.0	9.9	11.7	13.5	15.4	17.2	17.2	17.2	17.2
Off-Cycle Credits	-	1.7	3.3	5.0	6.7	8.3	10.0	10.0	10.0	10.0	-	1.7	3.3	5.0	6.7	8.3	10.0	10.0	10.0	10.0

In addition to these refinements to the estimation of the quantities of adjustments earned over time by each manufacturer, the agencies revised the CAFE model to apply estimates of the corresponding costs. For today's analysis, the agencies applied estimates developed previously by EPA, adjusting these value to 2019 dollars. The following table summarizes inputs through model year 2030:

Table VI-11 – Estimated Costs ($ per g/mi) for A/C and Off-Cycle Adjustments

Model Year	A/C Efficiency	A/C Leakage	Off-Cycle
2017	4.57	11.43	89.59
2018	4.48	11.20	87.48
2019	4.39	10.97	85.37
2020	4.30	10.76	83.79
2021	4.22	10.54	82.21
2022	4.13	10.33	81.16
2023	4.05	10.12	79.58
2024	3.97	9.92	78.52
2025	3.89	9.72	77.47
2026	3.81	9.53	76.31
2027	3.73	9.34	75.16
2028	3.66	9.15	74.04
2029	3.59	8.97	72.92
2030	3.52	8.79	71.83

The model currently accounts for any off-cycle adjustments associated with technologies that are included in the set of fuel-saving technologies explicitly simulated as part of this proposal (for example, start-stop systems that reduce fuel consumption during idle or active grille shutters that improve aerodynamic drag at highway speeds) and accumulates these adjustments up to the 10 g/mi cap. As a practical matter, most of the adjustments for which manufacturers are claiming off-cycle FCIV exist outside of the technology tree, so the cap is rarely reached during compliance simulation. The agencies have considered the potential to model their application explicitly. However, doing so would require data regarding which vehicle models already possess these improvements as well as the cost and expected value of applying them to other models in the future. Such data is currently too limited to support explicit modeling of these technologies and adjustments.

c) Alternative Fuel Vehicles

When establishing maximum feasible fuel economy standards, NHTSA is prohibited from considering the availability of alternatively fueled vehicles,[332] and credit provisions related

[331] These values are specified in the "market_ref.xlsx" input file's "Credits and Adjustments" worksheet. The file is available with the archive of model inputs and outputs posted at https://www.nhtsa.gov/corporate-average-fuel-economy/compliance-and-effects-modeling-system.
[332] 49 U.S.C. 32902(h).

to AFVs that significantly increase their fuel economy for CAFE compliance purposes. Under the "standard setting" perspective, these technologies (pure battery electric vehicles and fuel cell vehicles[333]) are not available in the compliance simulation to improve fuel economy. Under the "unconstrained" perspective, such as is documented in the DEIS and FEIS, the CAFE model considers these technologies in the same manner as other available technologies, and may apply them if they represent cost-effective compliance pathways. However, under both perspectives, the analysis continues to include dedicated AFVs that already exist in the MY 2017 fleet (and their projected future volumes). Also, because the CAA ~~provides no direction regarding~~allows consideration of alternative fuels, the final rule's analysis includes simulation of the *potential* that some manufacturers might introduce new AFVs in response to CO_2 standards. To represent the compliance benefit from such a response fully, NHTSA modified the CAFE model to include the specific provisions related to AFVs under the CO_2 standards. In particular, the CAFE model now carries a full representation of the production multipliers related to electric vehicles, fuel cell vehicles, plug-in hybrids, and CNG vehicles, all of which vary by year through MY 2021.

Commented [A135]: CHANGE AS SHOWN: Correcting CAA references.

EPCA also provides that CAFE levels may, subject to limitations, be adjusted upward to reflect the sale of flexible fuel vehicles (FFVs). Although these adjustments end after model year 2020, the final rule's analysis, like the NPRM's, includes estimated potential use through MY 2019, as summarized below:

Table VI-12 – Estimates of Earned FFV Credit (mpg)

Manufacturer	Passenger Cars			Light Trucks		
	2017	2018	2019	2017	2018	2019
BMW	-	-	-	-	-	-
Daimler	0.6	0.4	0.2	0.6	0.4	0.2
FCA	0.6	0.4	0.2	0.6	0.4	0.2
Ford	0.6	0.4	0.2	0.6	0.4	0.2
General Motors	0.6	0.4	0.2	0.6	0.4	0.2
Honda	-	-	-	-	-	-
Hyundai Kia-H	-	-	-	-	-	-
Hyundai Kia-K	-	-	-	-	-	-
JLR	-	-	-	-	-	-
Mazda	-	-	-	-	-	-
Mitsubishi	-	-	-	-	-	-
Nissan	-			-		
Subaru	-	-	-	-	-	-
Tesla	-	-	-	-	-	-
Toyota	-	-	-	0.6	0.4	0.2
Volvo	-	-	-	-	-	-
VWA	-	-	-	0.6	0.4	0.2

For its part, EPA has provided that manufacturers selling sufficient numbers of PHEVs, BEVs, and FCVs may, when calculating fleet average CO_2 levels, "count" each unit of

[333] Dedicated compressed natural gas (CNG) vehicles should also be excluded in this perspective but are not considered as a compliance strategy under any perspective in this analysis.

production as more than a single unit. The CAFE model accounts for these "multipliers." As for the NPRM, the final rule's analysis applies the following multipliers:

Table VI-13 – Production "Multipliers" for CNG Vehicles, PHEVs, BEVs, and FCVs

Model Year	CNG or PHEV	BEV or FCV
2017	1.60	2.00
2018	1.60	2.00
2019	1.60	2.00
2020	1.45	1.75
2021	1.30	1.50
2022	1.00	1.00

For example, under EPA's current regulation, when calculating the average CO_2 level *achieved* by its MY 2019 passenger car fleet, a manufacturer may treat each 1,000 BEVs as 2,000 BEVs. When calculating the average level *required* of this fleet, the manufacturer must use the actual production volume (in this example, 1,000 units). Similarly, the manufacturer must use the actual production volume when calculating compliance credit balances.

Commented [A136]: **REVISE:** It should be noted that EPA is in this final rule extending the multiplier for NGVs to 2.0 for MYs 2022-2026, regardless of how the program was modeled.

For the final rule's analysis, the CAFE model can be exercised in a manner that simulates these current EPA requirements, or that simulates two alternative approaches. The first includes the above-mentioned multipliers in the calculation of average requirements, and the second also includes the multipliers in the calculation of credit balances. The central analysis reflects current regulations. The sensitivity analysis presented in the FRIA includes a case applying multipliers to the calculation of achieved and required average CO_2 levels, and calculation of credit balances.

Commented [A137]: **REVISE:** The Oct-3 2019 model version reviewed by EPA does not characterize the multipliers according to either current or proposed regulations.

3. Civil Penalties

Throughout the history of the CAFE program, some manufacturers have consistently achieved fuel economy levels below applicable standards, electing instead to pay civil penalties as specified by EPCA. As in previous versions of the CAFE model, the current version allows the user to specify inputs identifying such manufacturers and to consider their compliance decisions as if they are willing to pay civil penalties for non-compliance with the CAFE program. As with the NPRM, the civil penalty rate in the current analysis is $5.50 per 1/10 of a mile per gallon, per vehicle manufactured for sale.

NHTSA notes that treating a manufacturer as if it is willing to pay civil penalties does not necessarily mean that it is expected to pay penalties in reality. Doing so merely implies that the manufacturer will only apply fuel economy technology up to a point, and then stop, regardless of whether or not its corporate average fuel economy is above its standard. In practice, we expect that many of these manufacturers will continue to be active in the credit market, using trades with other manufacturers to transfer credits into specific fleets that are challenged in any given year, rather than paying penalties to resolve CAFE deficits. The CAFE model calculates the amount of penalties paid by each manufacturer, but it does not simulate trades between

manufacturers. In practice, some (possibly most) of the total estimated penalties may be a transfer from one OEM to another.

Although EPCA, as amended in 2007 by the Energy Independence and Security Act (EISA), prescribes these specific civil penalty provisions for CAFE standards, the Clean Air Act (CAA) does not contain similar provisions for light-duty vehicles. Rather, the CAA~~'s provisions regarding noncompliance constitute a *de facto* prohibition against selling vehicles failing to comply with~~ prohibits sale of a new motor vehicle that is not covered by an EPA certificate of conformity, and in order to receive such a certificate the new motor vehicle must meet EPA's section 202 ~~fails to meet~~regulations, including applicable emissions standards. Therefore, inputs regarding civil penalties—including inputs regarding manufacturers' potential willingness to treat civil penalty payment as an economic choice—apply only to simulation of CAFE standards. On the other hand, some of the same manufacturers recently opting to pay civil penalties instead of complying with CAFE standards have also recently led adoption of lower-GWP refrigerants, and the "A/C leakage" credits count toward compliance only with CO_2 standards, not CAFE standards. The model accounts for this difference between the programs.

Commented [A138]: CHANGE AS SHOWN: Its not a de facto prohibition, it is a statutory prohibition (de jure) against selling a car that does not match the certificate of conformity.

When considering technology applications to improve fleet fuel economy, the model will add technology up to the point at which the effective cost of the technology (which includes technology cost, consumer fuel savings, consumer welfare changes, and the cost of penalties for non-compliance with the standard) is less costly than paying civil penalties or purchasing credits. Unlike previous versions of the model, the current implementation further acknowledges that some manufacturers experience transitions between product lines where they rely heavily on credits (either carried forward from earlier model years or acquired from other manufacturers) or simply pay penalties in one or more fleets for some number of years. The model now allows the user to specify, when appropriate for the regulatory program being simulated, on a year-by-year basis, whether each manufacturer should be considered as willing to pay penalties for non-compliance. This provides additional flexibility, particularly in the early years of the simulation. As discussed above, this assumption is best considered as a method to allow a manufacturer to under-comply with its standard in some model years—treating the civil penalty rate and payment option as a proxy for other actions it may take that are not represented in the CAFE model (e.g., purchasing credits from another manufacturer, carry-back from future model years, or negotiated settlements with NHTSA to resolve deficits).

For the NPRM, NHTSA relied on past compliance behavior and certified transactions in the credit market to designate some manufacturers as willing to pay CAFE penalties in some model years. The full set of NPRM assumptions regarding manufacturer behavior with respect to civil penalties is presented in Table-VI-14Table-VI-14, which shows all manufacturers were assumed to be willing to pay civil penalties prior to MY 2020. This was largely a reflection of either existing credit balances (which manufacturers will use to offset CAFE deficits until the credits reach their expiration dates) or inter-manufacturer trades assumed likely to happen in the near future, based on previous behavior. The manufacturers in the table whose names appear in bold all had at least one regulated fleet (of three) whose CAFE was below its standard in MY 2016. Because the NPRM analysis began with the MY 2016 fleet, and no technology could be added to vehicles that are already designed and built, all manufacturers could generate civil penalties in MY 2016. However, once a manufacturer is designated as unwilling to pay

penalties, the CAFE model will attempt to add technology to the respective fleets to avoid shortfalls.

Table-VI-14 – NPRM Assumptions Regarding Manufacturer Willingness to Pay Civil Penalties

Manufacturer	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
BMW	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Daimler	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
FCA	Y	Y	Y	Y	Y	Y	Y	Y	Y	N
Ford	Y	Y	Y	N	N	N	N	N	N	N
General Motors	Y	Y	Y	N	N	N	N	N	N	N
Honda	Y	Y	Y	N	N	N	N	N	N	N
Hyundai Kia-H	Y	Y	Y	N	N	N	N	N	N	N
Hyundai Kia-K	Y	Y	Y	N	N	N	N	N	N	N
JLR	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mazda	Y	Y	Y	N	N	N	N	N	N	N
Nissan Mitsubishi	Y	Y	Y	N	N	N	N	N	N	N
Subaru	Y	Y	Y	N	N	N	N	N	N	N
Tesla	Y	Y	Y	N	N	N	N	N	N	N
Toyota	Y	Y	Y	N	N	N	N	N	N	N
Volvo	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
VWA	Y	Y	Y	N	N	N	N	N	N	N

Several of the manufacturers in Table-VI-14Table-VI-14 that were presumed to be willing to pay civil penalties in the early years of the program have no history of paying civil penalties. However, several of those manufacturers have either bought or sold credits—or transferred credits from one fleet to another to offset a shortfall in the underperforming fleet. As the CAFE model does not simulate credit trades between manufacturers, providing this additional flexibility in the modeling avoids the outcome where the CAFE model applies more technology than needed in the context of the full set of compliance flexibilities at the industry level. By statute, NHTSA cannot consider credit flexibilities when setting standards, so most manufacturers (those without a history of civil penalty payment) are assumed to comply with their standards through fuel economy improvements for the model years being considered in this analysis. The notable exception to this assumption is Fiat Chrysler Automobiles (FCA), which could still satisfy the requirements of the program through a combination of credit application and civil penalties through MY 2025 before eventually complying exclusively through fuel economy improvements in MY 2026.

As mentioned above, the CAA does not provide for civil penalt~~ies provisions~~ in lieu of compliance with the standards similar to ~~these~~ provisions specified in EPCA/EISA, and the above-mentioned corresponding inputs apply only to simulation of compliance with CAFE standards.

Commented [A139]: CHANGE AS SHOWN: The CAA has civil penalty provisions for noncompliance.

Some stakeholders offering comments related to the analytical treatment of civil penalties indicated that NHTSA should tend toward assuming manufacturers will take advantage of this EPCA provision as an economically attractive alternative to compliance. Other commenters implied that NHTSA should tend toward not relying on compliance flexibilities in the analysis used to determine the maximum feasible stringency of CAFE standards. For example, New York University's Institute for Policy Integrity (IPI) offered the following comments:

> *NHTSA assumes that most manufacturers will be unwilling to pay penalties based in part on the fact that most manufacturers have not paid penalties in recent years. The Proposed Rule cites the statutory prohibition on NHTSA considering credit trading as a reason to assume manufacturers without a history of paying penalties will comply through technology alone, whatever the cost. But this is an arbitrary assumption and is in no way dictated by the statute. NHTSA knows as much, since elsewhere in the proposed rollback, the agency explains "EPCA is very clear as to which flexibilities are not to be considered" and NHTSA is allowed to consider off-cycle adjustments because they are not specifically mentioned. But considering penalties are not mentioned as off-limits for NHTSA in setting the standards either. Instead, the prohibition focuses on credit trading and transferring. The penalty safety valve has existed in EPCA for decades, and Congress clearly would have known how to add penalties to the list of trading and transferring. The fact that Congress did not bar NHTSA from considering penalties as a safety valve means that NHTSA must consider manufacturer's efficient use of penalties as a costminimizing compliance option. Besides, NHTSA does consider penalties for some of the manufacturers making its statutory justification even less rational.*[334]

On the other hand, in more general comments about NHTSA's analytical treatment of program flexibilities, FCA stated that "when flexibilities are considered while setting targets, they cease to be flexibilities and become simply additional technology mandates."[335]

NHTSA agrees with IPI that EPCA does not expressly prohibit NHTSA, when conducting analysis supporting determinations of the maximum feasible stringency of future CAFE standards, from including manufacturers' potential tendency to pay civil penalities rather than complying with those standards. However, EPCA also does not *require* NHTSA to include this tendency in its analysis. NHTSA also notes, as does IPI, that EPCA *does* prohibit NHTSA from including credit trading, transferring, or the availability of credits in such analysis (although NHTSA interprets this prohibition to apply only to the model years for which standards are being set). This statutory difference is logical based on the way credits and penalties function differently under EPCA. Because credits help manufacturers achieve compliance with CAFE standards, absent the statutory prohibition, credits would be relevant to the feasibility of a

[334] Institute for Policy Integrity, NHTSA-2018-0067-12213, at 24.
[335] FCA, [add docket number], at 6.

standard.[336] Penalties, on the other hand, do not enable a manufacturer to comply with an applicable standard; penalties are for noncompliance.[337] When Congress added credit trading provisions to EPCA in 2007, NHTSA anticipated that competitive considerations would make manufacturers reluctant to engage in such trades. Since that time, manufacturers actually have demonstrated otherwise, although the reliance on trading—especially between specific pairs of OEMs—appears to vary widely. At this time, NHTSA considers it most likely that manufacturers will shift away from paying civil penalties and toward compliance credit trading. Consequently, for NHTSA to include civil penalty payment in its analysis would increasingly amount to using civil penalty payment as an analytical proxy for credit trading. Having further considered the question, NHTSA's current view is, therefore, that including civil penalty payment beyond MY 2020 would effectively subvert EPCA's prohibition against considering credit trading. Therefore, for today's announcement, NHTSA has modified its analysis to assume that BMW, Daimler, FCA, JLR, and Volvo would consider paying civil penalties through MY 2020, and that all manufacturers would apply as much technology as would be needed in order to avoid paying civil penalties after MY 2020.

4. Technology Effectiveness Values

The next input required to simulate manufacturers' decision-making processes for the year-by-year application of technologies to specific vehicles is estimates of how effective each technology would be at reducing fuel consumption. In the NPRM, we used full-vehicle modeling and simulation to estimate the fuel economy improvements manufacturers could make to a fleet of vehicles, considering those vehicles' technical specifications and how combinations of technologies interact. Full-vehicle modeling and simulation uses computer software and physics-based models to predict how combinations of technologies perform as a full system under defined conditions.

A model is a mathematical representation of a system, and simulation is the behavior of that mathematical representation over time. In this analysis, the model is a mathematical representation of an entire vehicle,[338] including its individual components such as the engine and transmission, overall vehicle characteristics such as mass and aerodynamic drag, and the environmental conditions, such as ambient temperature and barometric pressure. We simulated the model's behavior over test cycles, including the 2-cycle laboratory compliance tests (or 2-cycle tests),[339] to determine how the individual components interact. 2-cycle tests are test cycles

[336] *See* 49 U.S.C. 32911(b) ("Compliance is determined after considering credits available to the manufacturer . . . .").

[337] *See id.*

[338] Our full vehicle model was composed of sub-models, which is why the full vehicle model could also be referred to as a full system model, composed of sub-system models.

[339] EPA's compliance test cycles are used to measure the fuel economy of a vehicle. For readers unfamiliar with this process, it is like running a car on a treadmill following a program—or more specifically, two programs. The "programs" are the "urban cycle," or Federal Test Procedure (abbreviated as "FTP"), and the "highway cycle," or Highway Fuel Economy Test (abbreviated as "HFET"), and they have not changed substantively since 1975. Each cycle is a designated speed trace (of vehicle speed versus time) that all certified vehicles must follow during testing. The FTP is meant roughly to simulate stop and go city driving, and the HFET is meant roughly to simulate steady flowing highway driving at about 50 mph. For further details on compliance testing, see the discussion in [Section XX].

that are used to measure fuel economy and emissions for CAFE and CO_2 compliance, and therefore are the relevant test cycles for determining technology effectiveness when establishing standards. In the laboratory, 2-cycle testing involves sophisticated test and measurement equipment, carefully controlled environmental conditions, and precise procedures to provide the most repeatable results possible with human drivers. Measurements using these structured procedures serve as a yardstick for fuel economy and CO_2 emissions.

Full-vehicle modeling and simulation was initially developed to avoid the costs of designing and testing prototype parts for every new type of technology. For example, if a truck manufacturer has a concept for a lightweight tailgate and wants to determine the fuel economy impact for the weight reduction, the manufacturer can use physics-based computer modeling to estimate the impact. The vehicle, modeled with the proposed change, can be simulated on a defined test route and under a defined test condition, such as city or highway driving in warm ambient temperature conditions, and compared against the baseline reference vehicle. Full-vehicle modeling and simulation allows the consideration and evaluation of different designs and concepts before building a single prototype. ~~It also avoids test repeatability issues that are unavoidable in laboratory testing, such as differences in how vehicles are driven over the test cycle by human drivers, variations in emissions measurement equipment, and variations in environmental conditions.~~[340]

Commented [A140]: DELETE: This point is irrelevant to describing the benefits of full vehicle simulation. It is not necessary to disparage lab testing.

Full-vehicle modeling and simulation requires detailed data describing the individual technologies and performance-related characteristics. Those specifications generally come from design specifications, laboratory measurements, and other subsystem simulations or modeling. One example of data used as an input to the full vehicle simulation are engine maps for each engine technology that define how much fuel is consumed by the engine technology across its operating range.

Using full-vehicle modeling and simulation to estimate technology efficiency improvements has two primary advantages over using single or limited point estimates. An analysis using single or limited point estimates may assume that, for example, one fuel economy improving technology with an effectiveness value of 5% by itself and another technology with an effectiveness value of 10% by itself, when applied together achieve an additive improvement of 15%. Single point estimates generally do not provide accurate effectiveness values because they do not capture complex relationships among technologies. Technology effectiveness often differs significantly depending on the vehicle type (e.g. sedan versus pickup truck) and how the technology interacts with other technologies on the vehicle, as different technologies may provide different incremental levels of fuel economy improvement if implemented alone or in tandem with other technologies. Any oversimplification of these complex interactions leads to less accurate and often overestimated effectiveness estimates.

In addition, because manufacturers often implement several fuel-saving technologies simultaneously when redesigning a vehicle, it is difficult to isolate the effect of individual

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~~[340] Difficulty with controlling for such variability is reflected, for example, in 40 CFR 1065.210, Work input and output sensors, which describes complicated instructions and recommendations to help control for variability in real world (non-simulated) test instrumentation set-up.~~

technologies using laboratory measurement of production vehicles alone. Modeling and simulation offers the opportunity to isolate the effects of individual technologies by using a single or small number of baseline vehicle configurations and incrementally adding technologies to those baseline configurations. This provides a consistent reference point for the incremental effectiveness estimates for each technology and for combinations of technologies for each vehicle type. Vehicle modeling also reduces the potential for overcounting or undercounting technology effectiveness.

An important feature of this analysis is that the *incremental* effectiveness of each technology and combinations of technologies be accurate and relative to a consistent baseline vehicle. The *absolute* fuel economy values of the full vehicle simulations are used only to determine *incremental* effectiveness and are never used directly to assign an absolute fuel economy value to any vehicle model or configuration for the rulemaking analysis.

For this analysis, absolute fuel economy levels are based on the individual fuel economy values from CAFE compliance data for each vehicle in the baseline fleet. The incremental effectiveness from the full vehicle simulations performed in Autonomie, a physics-based full-vehicle modeling and simulation software developed and maintained by the U.S. Department of Energy's Argonne National Laboratory, are applied to baseline fuel economy to determine the absolute fuel economy of applying the first technology change. For subsequent technology changes, incremental effectiveness is applied to the absolute fuel economy level of the previous technology configuration.

For example, if a Ford F150 2-wheel drive crew cab and short bed in the baseline fleet has a fuel economy value of 30 mpg for CAFE compliance, 30 mpg will be considered the reference absolute fuel economy value. A similar full vehicle model in the Autonomie simulation may begin with an average fuel economy value of 32 mpg, and with incremental addition of a specific technology X its fuel economy improves to 35 mpg, a 9.3% improvement. In this example, the incremental fuel economy improvement (9.3%) from technology X would be applied to the F150's 30 mpg absolute value.

For this analysis, the agencies determined the incremental effectiveness of technologies as applied to the 2,952 unique vehicle models in the analysis fleet. Although, as mentioned above, full-vehicle modeling and simulation reduces the work and time required to assess the impact of moving a vehicle from one technology state to another, it would be impractical – if not impossible—to build a unique vehicle model for every individual vehicle in the analysis fleet. Therefore, as explained further below, vehicle models are built in a way that maintains similar attributes to the analysis fleet vehicles, which ensures key components are reasonably represented.

We received a wide array of comments regarding the full-vehicle modeling and simulation performed for the NPRM, but there was general agreement that full-vehicle modeling and simulation was the appropriate method to determine technology effectiveness.[341]

[341] *See* NHTSA-2018-0067-12039; NHTSA-2018-0067-12073. UCS and AAM both agreed that full vehicle simulation can significantly improve the estimates of technology effectiveness.

Stakeholders commented on other areas, such as full vehicle simulation tools, inputs, and assumptions, and these comments will be discussed in the following sections. For this final rule, the agencies continued to use the same full-vehicle simulation approach to estimate technology effectiveness for technology adoption in the rulemaking timeframe. The next sections will discuss the details of the explicit input specifications and assumptions used for the final rule analysis.

a) Why We Used Autonomie Full-Vehicle Modeling and Simulation to Determine Technology Effectiveness

The NPRM and final rule analysis use effectiveness estimates for technologies developed using Autonomie, a physics-based full-vehicle modeling and simulation software developed and maintained by the U.S. Department of Energy's Argonne National Laboratory (ANL).[342] Autonomie was designed to serve as a single tool to meet requirements of automotive engineering throughout the vehicle development process, and has been under continuous improvement by ANL for over 20 years. Autonomie is commercially available and widely used in the automotive industry by suppliers, automakers, and academic researchers (who publish findings in peer reviewed academic journals).[343] DOE and manufacturers have used Autonomie and its ability to simulate a large number of powertrain configurations, component technologies, and vehicle-level controls over numerous drive cycles to support studies on fuel efficiency, cost-benefit analysis, and carbon dioxide emissions,[344] and other topics.

Autonomie has also been used to provide the U.S. government with data to make decisions about future research, and is used by DOE for analysis supporting budget priorities and plans for programs managed by its Vehicle Technologies Office (VTO), and to support decision making among competing vehicle technology research and development projects.[345] In addition, Autonomie is the primary vehicle simulation tool used by DOE to support its U.S. DRIVE program, a government-industry partnership focused on advanced automotive and related energy infrastructure technology research and development.[346]

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[342] More information about Autonomie is available at https://www.anl.gov/technology/project/autonomie-automotive-system-design (last accessed June 21, 2018). As mentioned in the preliminary regulatory impact analysis (PRIA) for this rule, the agencies used Autonomie version R15SP1, the same version used for the 2016 Draft TAR.

[343] Rousseau, A. Shidore, N. Karbowski, D. Sharer, "*Autonomie Vehicle Validation Summary*." https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/anl-autonomie-vehicle-model-validation-1509.pdf.

[344] Delorme et al. 2008, Rousseau, A, Sharer, P, Pagerit, S., & Das, S. "*Trade-off between Fuel Economy and Cost for Advanced Vehicle Configurations*," 20th International Electric Vehicle Symposium (EVS20), Monaco (April 2005); Elgowainy, A., Burnham, A., Wang, M., Molburg, J., & Rousseau, A. "*Well-To-Wheels Energy Use and Greenhouse Gas Emissions of Plug-in Hybrid Electric Vehicles*," SAE 2009-01-1309, SAE World Congress, Detroit, April 2009.

[345] U.S. DOE Benefits & Scenario Analysis publications is available at https://www.autonomie.net/publications/fuel_economy_report.html (last accessed September 11, 2019).

[346] For more information on U.S. Drive, see https://www.energy.gov/eere/vehicles/us-drive.

Autonomie is a MathWorks-based software environment and framework for automotive control-system design, simulation, and analysis.[347] It is designed for rapid and easy integration of models with varying levels of detail (low to high fidelity), abstraction (from subsystems to systems and entire architectures), and processes (e.g., calibration, validation). By building models automatically, Autonomie allows the quick simulation of many component technologies and powertrain configurations, and, in this case, to assess the energy consumption of advanced powertrain technologies. Autonomie simulates subsystems, systems, or entire vehicles; evaluates and analyzes fuel efficiency and performance; performs analyses and tests for virtual calibration, verification, and validation of hardware models and algorithms; supports system hardware and software requirements; links to optimization algorithms; and supplies libraries of models for propulsion architectures of conventional powertrains as well as hybrid and electric vehicles.

With hundreds of pre-defined powertrain configurations along with vehicle level control strategies developed from dynamometer test data, Autonomie is an ~~ideal~~ appropriate tool for analyzing advantages and drawbacks of applying different technology options within each technology family, including conventional, parallel hybrid, series hybrid, power-split hybrid electric vehicles (HEVs), battery electric vehicles (BEV) and fuel cell vehicles (FCVs). Autonomie also allows users to evaluate the effect of component sizing on fuel consumption for different powertrain technologies as well as to define component requirements (e.g., power, energy) to maximize fuel displacement for a specific application.[348] To evaluate properly any powertrain-configuration or component-sizing influence, vehicle-level control models are critical, especially for electric drive vehicles like hybrids and plug-in hybrids. Argonne has extensive expertise in developing vehicle-level control models based on different approaches, from global optimization to instantaneous optimization, rule-based optimization, and heuristic optimization.[349]

Commented [A141]: CHANGE AS SHOWN: Unnecessary overstatement. In general, a model could be described as "appropriate" or even "the best available", but no model of anything in the world should be described as "ideal", unless of course, the model is the thing itself, in which case it's obviously not very useful as a model.

Autonomie has been developed to consider real-world vehicle metrics like performance, hardware limitations, utility, and drivability metrics (e.g., towing capability, shift busyness, frequency of engine on/off transitions), which are important to producing realistic estimates of fuel economy and CO_2 emission rates. This increasing realism has, in turn, steadily increased confidence in the appropriateness of using Autonomie to make significant investment decisions.

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[347] Halbach, S. Sharer, P. Pagerit, P., Folkerts, C. & Rousseau, A. "*Model Architecture, Methods, and Interfaces for Efficient Math-Based design and Simulation of Automotive Control Systems*," SAE 2010-01-0241, SAE World Congress, Detroit, April, 2010.

[348] Nelson, P., Amine, K., Rousseau, A., & Yomoto, H. (EnerDel Corp.), "Advanced Lithium-ion Batteries for Plug-in Hybrid-electric Vehicles," 23rd International Electric Vehicle Symposium (EVS23), Anaheim, CA, (Dec. 2007); Karbowski, D., Haliburton, C., & Rousseau, A. "Impact of Component Size on Plug-in Hybrid Vehicles Energy Consumption using Global Optimization," 23rd International Electric Vehicle Symposium (EVS23), Anaheim, CA, (Dec. 2007).

[349] Karbowski, D., Kwon, J., Kim, N., & Rousseau, A., "Instantaneously Optimized Controller for a Multimode Hybrid Electric Vehicle," SAE paper 2010-01-0816, SAE World Congress, Detroit, April 2010; Sharer, P., Rousseau, A., Karbowski, D., & Pagerit, S. "Plug-in Hybrid Electric Vehicle Control Strategy - *Comparison between EV and Charge-Depleting Options*," SAE paper 2008-01-0460, SAE World Congress, Detroit (April 2008); and Rousseau, A., Shidore, N., Carlson, R., & Karbowski, D. "*Impact of Battery Characteristics on PHEV Fuel Economy*," AABC08.

Antonomie has also been validated for a number of powertrain configurations and vehicle classes using Argonne's Advanced Mobility Technology Laboratory (AMTL) (formerly Advanced Powertrain Research Facility, or APRF) vehicle test data.[350]

ANL has spent several years developing, applying, and expanding the means to use distributed computing to exercise its Autonomie full-vehicle simulation tool over the scale necessary for realistic analysis to provide data for CAFE and CO_2 standards rulemaking. The NPRM and PRIA detailed how ANL used Autonomie to estimate the fuel economy impacts for roughly a million combinations of technologies and vehicle types.[351, 352] ANL developed input parameters for Autonomie to represent every combination of vehicle, powertrain, and component technologies considered in this rulemaking. The sequential addition of more than 50 fuel economy-improving technologies to ten vehicle types generated more than 140,000 unique technology and vehicle combinations. Running the Autonomie powertrain sizing algorithms to determine the appropriate amount of engine downsizing needed to maintain overall vehicle performance when vehicle mass reduction is applied and for certain engine technology changes (discussed further, below) increased the total number of simulations to more than one million. The result of these simulations is a useful dataset identifying the impacts of combinations of vehicle technologies on energy consumption—a dataset that can be referenced as an input to the CAFE model for assessing regulatory compliance alternatives.

The following sections discuss the full-vehicle modeling and simulation inputs and data assumptions, and comments received on the NPRM analysis. The discussion is necessarily technical, but also important to understand the agencies' decisions to modify (or not) the Autonomie analysis for the final rule.

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[350] Jeong, J., Kim, N., Stutenberg, K., Rousseau, A., "Analysis and Model Validation of the Toyota Prius Prime". SAE 2019-01-0369, SAE World Congress, Detroit, April 2019; Kim, N, Jeong, J. Rousseau, A. & Lohse-Busch, H. "Control Analysis and Thermal Model Development of PHEV," SAE 2015-01-1157, SAE World Congress, Detroit, April 2015; Kim, N., Rousseau, A. & Lohse-Busch, H. "Advanced Automatic Transmission Model Validation Using Dynamometer Test Data," SAE 2014-01-1778, SAE World Congress, Detroit, Apr. 14; Lee, D. Rousseau, A. & Rask, E. "Development and Validation of the Ford Focus BEV Vehicle Model," 2014-01-1809, SAE World Congress, Detroit, Apr14; Kim, N., Kim, N., Rousseau, A., & Duoba, M. "Validating Volt PHEV Model with Dynamometer Test Data using Autonomie," SAE 2013-01-1458, SAE World Congress, Detroit, Apr. 13; Kim, N., Rousseau, A., & Rask, E. "Autonomie Model Validation with Test Data for 2010 Toyota Prius," SAE 2012-01-1040, SAE World Congress, Detroit, Apr12; Karbowski, D., Rousseau, A, Pagerit, S., & Sharer, P. "Plug-in Vehicle Control Strategy - From Global Optimization to Real Time Application," 22th International Electric Vehicle Symposium (EVS22), Yokohama, (October 2006).

[351] As part of the Argonne simulation effort, individual technology combinations simulated in Autonomie were paired with Argonne's BatPAC model to estimate the battery cost associated with each technology combination based on characteristics of the simulated vehicle and its level of electrification. Information regarding Argonne's BatPAC model is available at http://www.cse.anl.gov/batpac/.

[352] Additionally, the impact of engine technologies on fuel consumption, torque, and other metrics was characterized using GT POWER simulation modeling in combination with other engine modeling that was conducted by IAV Automotive Engineering, Inc. (IAV). The engine characterization "maps" resulting from this analysis were used as inputs for the Autonomie full-vehicle simulation modeling. Information regarding GT Power is available at https://www.gtisoft.com/gt-suite-applications/propulsion-systems/gt-power-engine-simulation-software.

(1) Full-Vehicle Modeling, Simulation Inputs and Data Assumptions

The agencies provided extensive documentation that quantitatively and qualitatively described the over 50 technologies considered as inputs to the Autonomie modeling.[353, 354] These inputs consisted of engine technologies, transmission technologies, powertrain electrification, light-weighting, aerodynamic improvements, and tire rolling resistance improvements.[355] The PRIA provided an overview of the sub-models for each technology, including the internal combustion engine model, automatic transmission model, and others.[356] The ANL NPRM model documentation expanded on these sub-models in detail to show the interaction of each sub-model input and output.[357] For example, as shown in Figure VI-1Figure VI-1, the input for Autonomie's driver model (i.e., the model used to approximate the driving behavior of a real driver) is vehicle speed, and outputs are accelerator pedal, brake pedal, and torque demand.

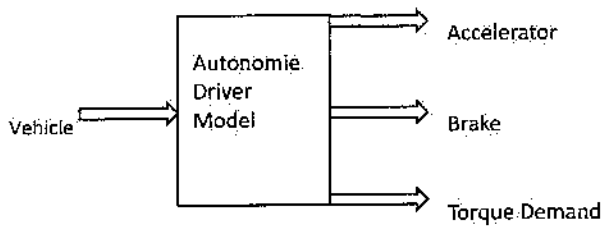

Figure VI-1 - Autonomie Driver Sub-Model inputs and outputs

Effectiveness inputs for the NPRM and the final rule analysis were specifically developed to consider many real world and compliance test cycle constraints, to the extent a computer model could capture them. Examples include the advanced engine knock model discussed below, in addition to other constraints like allowing cylinder deactivation to occur in ways that would not negatively impact noise-vibration-harshness (NVH), and similarly optimizing the number of engine on/off events (e.g., from start/stop 12V micro hybrid systems) to balance between effectiveness and NVH.

[353] NHTSA-2018-0067-12299. Preliminary Regulatory Impact Analysis (July 2018).
[354] NHTSA-2018-0067-0007. Islam, E., S, Moawad, A., Kim, N, Rousseau, A. "A Detailed Vehicle Simulation Process To Support CAFE Standards 04262018 – Report" ANL Autonomie Documentation. Aug 21, 2018. NHTSA-2018-0067-0004. ANL Autonomie Data Dictionary. Aug 21, 2018. NHTSA-2018-0067-0003. ANL Autonomie Summary of Main Component Assumptions. Aug 21, 2018. NHTSA-2018-0067-0005. ANL Autonomie Model Assumptions Summary. Aug 21, 2018. NHTSA-2018-0067-1692. ANL BatPac Model 12 55. Aug 21, 2018.
[355] SAFE Rule for MY2021-2026 PRIA Chapter 6.2.3 Technology groups in Autonomie simulations and CAFE model
[356] PRIA at 189.
[357] NHTSA-2018-0067-0007. Islam, E., S, Moawad, A., Kim, N, Rousseau, A. "A Detailed Vehicle Simulation Process To Support CAFE Standards 04262018 – Report" ANL Autonomie Documentation. Aug 21, 2018.

One major input used in the effectiveness modeling that the agencies provided key specifications for in the PRIA are engine fuel maps that define how an engine equipped with specific technologies operates over a variety of engine load (torque) and engine speed conditions. The engine maps used as inputs to the Autonomie analysis were developed by starting with a base map and then incrementally adding engine technologies to the base map. Although the same type of engine map is used for all technology classes, the effectiveness varies based on the characteristics of each vehicle type. For example, a compact car with a turbocharged engine will have different fuel economy and performance values than a pickup truck with the same engine technology type. Importantly, using this process to develop engine maps ensured that real-world constraints were considered for each vehicle type; for example, the agencies developed engine maps using IAV's GT-Power engine with an advanced knock model to ensure that engine operation was realistic throughout the test cycle.[358] The engine map specifications are discussed further in Section [xxx] of this preamble and Chapter [6] of FRIA.

Commented [A142]: REVISE: A refererence to the supporting docketed materials is needed here. From the text alone, it is not possible to tell what is currently being used within the Autonomie inputs since those have not been fully shared with EPA, but if the inputs are still based on the 2014-2018 IAV work, they did not use a fully-predictive, kinetics-fit knock model that is available as one of the knock model options within the v.2017 and later versions of GT-POWER. In our own work at EPA, we found significant differences in the model's ability to predict end-gas related combustion knock phenomena between a kinetics-fit model and the other models available within GT-power. When multiple technologies impacting knock are combined on an engine (e.g., cooled-EGR combined with high pressure ratio boosting and GDI, or Atkinson cycle combined with GDI and cooled-EGR), this can result in significant under- and/or over-prediction of CO2 emissions when engines operate near knock or preignition limits.

The agencies also provided key details about input assumptions for various vehicle specifications like transmission gear ratio, tire size, final drive ratios, and individual component weights.[359] Each of these assumptions, to some extent, varied between the ten technology classes to capture appropriately real-world vehicle specifications like wheel mass or fuel tank mass. These specific input assumptions were developed based on the latest test data and current market fleet information.[360] The agencies relied on default assumptions developed by the Autonomie team based on test data and technical publications for other technology inputs that Autonomie requires, like throttle time response and shifting strategies for different transmission technologies. Autonomie does not simulate vehicle attributes that have minute impacts, like whether a vehicle had a sun roof or hood scoops, as those attributes would have trivial impact in the overall analysis.

Because we model ten different vehicle types to represent the 2,952 vehicles in the baseline fleet, improper assumptions about an advanced technology could lead to errors in estimating effectiveness. Autonomie is a sophisticated full-vehicle mudeling tool that requires extensive technology characteristics based on both a physical and intangible data like proprietary software. With a few technologies, we did not have publicly available data, but had received confidential business information that such technologies would be available in the market in the rulemaking time frame. For such technologies, including advanced cylinder deactivation, we adopted a method in the CAFE model to represent the effectiveness of the technology. For those technologies, the agencies determined that effectiveness could reasonably be represented as a

[358] Engine Knock in spark ignition engines occurs when combustion of some of the air/fuel mixture in the cylinder does not result from propagation of the flame front ignited by the spark plug, but one or more pockets of air/fuel mixture explodes outside of the envelope of the normal combustion front.

[359] NHTSA-2018-0067-0005, ANL Autonomie Model Assumptions Summary, Aug 21, 2018. NHTSA-2018-0067-0003, ANL – Summary of Main Component Performance and Assumptions NPRM, Aug 21, 2018.

[360] See further details in the analysis fleet Section [xxx].

fixed value.[361] Effectiveness values for technologies not explicitly simulated in Autonomie are discussed further in the individual technology sections of this preamble.

Commented [A143]: REVISE: Incorrect statement in the footnote below: "The effectiveness of these technologies cannot be captured on the 2-cycle test..."

Some of the technologies listed may influence road load coefficients (LDB, SAX); others may have both on-cycle and off-cycle benefits (IACC, EPS); All of these technologies will have at least some on-cycle benefit over the 2-cycle test.

The agencies sought comments on all effectiveness inputs and input assumptions, including the specific data used to characterize the technologies, such as data to build the technology input, data representing operating range of technologies, and data for variation among technology inputs. The agencies also sought comment on the effectiveness values used for technologies not explicitly defined in Autonomie.

Meszler Engineering Services, commenting on behalf of the Natural Resources Defense Council, and ICCT questioned the accuracy of the effectiveness estimates in the ANL database, and as an example Meszler analyzed the fuel economy impacts of a 10-speed automatic transmission relative to a baseline 8-speed automatic transmission, concluding that the widely ranging effectiveness estimates were unexpected. ICCT questioned the accuracy of the IAV engine maps that serve as an input to the Autonomie effectiveness modeling, and asked whether those could "reasonably stand as a foundation for automotive developments and technology combinations" discussed elsewhere in their comments. ICCT also questioned whether Autonomie realistically and validly modeled synergies between technologies, using the effectiveness values from CEGR and transmissions as an example. Meszler stated that the agencies have an obligation to validate the Autonomie estimates before using them to support the NPRM or any other rulemaking. The agencies also received comments on the specific effectiveness estimates generated by Autonomie;, however, those comments will be discussed in each individual technology section, below.

Despite these criticisms, Meszler stated that the critiques of the Autonomie technology database were not meant to imply that the Autonomie vehicle simulation model used to develop the database was fundamentally flawed, or that the model could not be used to derive accurate fuel economy impact estimates. Meszler noted that, as with any model, estimates derived with Autonomie are only valid for a given set of modeling parameters and if those parameters are well defined, the estimates should be accurate and reliable. Conversely, if those parameters are not well defined, the estimates would be inaccurate and unreliable. Meszler stated that the agencies must make the full set of modeling assumptions used for the Autonomie database available for review and comment.

We agree with Meszler that, in general, when inputs to a model are inaccurate, output effectiveness results may be too high or too low. The technology effectiveness estimates from modeling results often vary with the type of vehicle and the other technologies that are on that vehicle.[362] The Autonomie output database consists of permutations of over 50 technologies for

[361] For final rule, 9 out of 50 plus technologies use fixed offset effectiveness values. The effectiveness of these technologies cannot be captured on the 2-cycle test or, like ADEAC, they are a new technology where robust data that could be used as an input to the technology effectiveness modeling does not yet exist. Specifically, these nine technologies are LDB, SAX, EPS, IACC, EFR, ADEAC, DSLI, DSLIAD and TURBOAD. [Reference CAFE model section discussing on how the agencies implemented ADEAC, DSLI, DSLIAD, EPS, LDX, SAX, IACC, EFR, TURBOAD)].

[362] The PRIA Chapter 6.2.2.1, Table 6-2 and Table 6-3 defined the characteristics of the reference technology classes that representative of the analysis fleet.

each of the ten technology classes simulated by the CAFE model. A wide range of effectiveness is expected when going from a baseline technology to an advanced technology across different technology classes because there are significant differences in how much power is required from the powertrain during 2-cycle testing across the ten vehicle types. This impacts powertrain operating conditions (e.g., engine speed and load) during 2-cycle testing. Fuel economy improving technologies have different effectiveness at each of those operating conditions so vehicles that have higher average power demands will have different effectiveness than vehicles with lower average power demands. Further, the differences in effectiveness at higher power and lower power vary by technology so the overall relationship is complex. Large-scale full-vehicle modeling and simulation account for these interactions and complexities.

Before conducting any full-vehicle modeling and simulation, the agencies spent a considerable amount of time and effort developing the specific inputs used for the Autonomie analysis. The agencies believe that these technology inputs provide reasonable estimates for the light-duty vehicle technologies the agencies expect to be available in the market in the rulemaking timeframe. As discussed earlier, these inputs vary in effectiveness due to how different vehicles, like compact cars and pickup trucks, operate on the 2-cycle test and in the real world. Some technologies, such as 10-speed automatic transmissions (AT10) relative to 8-speed automatic transmissions (AT8), can and should have different effectiveness results in the analysis between two different technology classes.[363] These unique synergistic effects can only be taken into account through conducting full-vehicle modeling and simulation, which the agencies did here.

With regards to Meszler's comment that the agencies have an obligation to validate the Autonomie estimates before using them to support the NPRM or any other rulemaking, the agencies would like to point Meszler to the description of the ANL Autonomie team's robust process for vehicle model validation that was contained in the PRIA.[364] To summarize, the NPRM and final rule analysis leveraged extensive vehicle test data collected by Argonne National Laboratory with funding from the U.S. DOE Vehicle Technologies Office.[365] Over the past 20 years, the ANL team has developed specific instrumentation lists and test procedures for collecting sufficient information to develop and validate full vehicle models. In addition, the agencies described the ANL team's efforts to validate specific component models as well, such as the advanced automatic transmission and dual clutch transmission models.[366]

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[363] Separately, the agencies modified specific transmission modeling parameters for the final rule after additional review, including a thorough review of public comments, and this review is discussed in detail in Section [X.X. – Transmissions].

[364] PRIA at 216-7. *See also* [ANL validation citations]; [ANL PPT of how it validates vehicles].

[365] A list of the vehicles that have been tested at the APRF can be found under http://www.anl.gov/energy-systems/group/downloadable-dynamometer-database.

[366] Kim, N., Rousseau, N., Lohse-Bush, H. "*Advanced Automatic Transmission Model Validation Using Dynamometer Test Data*," SAE 2014-01-1778, SAE World Congress, Detroit, April 2014; Kim, N., Lohse-Bush, H., Rousseau, A. "Development of a model of the dual clutch transmission in Autonomie and validation with dynamometer test data," *International Journal of Automotive Technologies*, March 2014, Volume 15, Issue 2, pp 263-71.

The agencies also described the process for validating inputs used to develop the IAV engine maps,[367] another input to the Autonomie modeling and simulations. Broadly, the assumptions and inputs to the modeling and validation of engine model results leveraged IAV's global engine database that included benchmarking data, engine test data, single cylinder test data and prior modeling studies, and also technical publications and information presented at conferences. The agencies referenced in the PRIA that engine maps were validated with engine dynamometer test data to the extent possible.[368] Because the NPRM and this final rule analysis considered some technologies not yet in production, the agencies relied on technical publications and engine modeling by IAV to develop and corroborate inputs and input assumptions where engine dynamometer test data was not available.

In addition, as described earlier in this section, the full set of NPRM modeling assumptions used for the Autonomie database were available for review and comment in the docket for this rulemaking.[369] The full set of modeling assumptions used for this final rule are also available in the docket.[370]

[Text forthcoming].

Both ICCT and Meszler also commented on the availability of technologies within the Autonomie database, with Meszler stating that with limited exceptions, technologies were not included in the NPRM CAFE model if they were not included in the simulation modeling that underlay the ANL database, and accordingly if a combination of technologies was not modeled during the development of the ANL database, that package (or combination) of technologies was not available for adoption in the CAFE model. Meszler stated that these constraints limited the slate of technologies available to respond to fuel economy standards, and independently expanding the model to include additional technologies or technology combinations is not trivial.

ICCT gave specific examples of key efficiency technologies that it stated Autonomie did not include, like advanced DEAC, VCR, Miller Cycle, e-boost, and HCCI. ICCT argued that this was especially problematic as the agencies appeared to have available engine maps from IAV on advanced DEAC, VCR, Miller Cycle, E-boost (and from advanced DEAC, VCR, Miller Cycle, E-boost, HCCI from EPA) that ANL or the agencies have been unable to or opted not to include in their modeling. ICCT stated that the agencies must disclose how Autonomie had been

Commented [A144]: REVISE: The discussion beginning on PRIA pg251 cross-referenced in the footnote only contains one mention of engine map validation, for Eng12 (turbo1.)

A link to docketed material beyond what was provided in the NPRM will be needed for this response. Note that the NPRM materials cited in footnote 369 also do not describe the validation process of the IAV engine maps, and include only a one or two sentence decription of the assumed technologies.

If 'validation' of other engine maps is simply referring to IAV's use of GT-POWER models, EPA will note that the generated maps extended well beyond the models' ability to accurately predict either abnormal combustion phenomena or CO2 and fuel consumption without signifant further calibration of the models vs. actual high-speed combustion data.

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[367] PRIA at 251.
[368] *See, e.g.*, PRIA at 288.
[369] NHTSA-2018-0067-0007. Islam, E., S. Moawad, A., Kim, N, Rousseau, A., "A Detailed Vehicle Simulation Process To Support CAFE Standards 04262018 – Report" ANL Autonomie Documentation. Aug 21, 2018.
NHTSA-2018-0067-0004. ANL Autonomie Data Dictionary. Aug 21, 2018.
NHTSA-2018-0067-0003. ANL Autonomie Summary of Main Component Assumptions. Aug 21, 2018.
NHTSA-2018-0067-0005. ANL Autonomie Model Assumptions Summary. Aug 21, 2018.
NHTSA-2018-0067-1692. ANL BatPac Model 12.55. Aug 21, 2018.
Preliminary Regulatory Impact Analysis (July 2018). Posted July 2018 and updated August 23 and October 16, 2018.
[370] [Cite to final rule documentation].

updated to incorporate "cutting edge" 2020-2025 automotive technologies to ensure they reflect available improvements.[371]

The agencies have updated the final rule analysis to include additional technologies. In the NPRM, the agencies presented the engine maps for all of the technologies that ICCT listed, except HCCI, and sought comment on the engine maps, technical assumptions and the potential use of the technologies for the final rule analysis. Based on the available technical information and the ICCT and Meszler comments, for the final rule analysis, VCR, Miller Cycle (VTG), and e-boost (VTGe with 48V BISG) technologies have been added and included in the Autonomie modeling and simulations, and advanced DEAC technology has been added using fixed point effectiveness estimates in the CAFE model analysis. The agencies disagree with ICCT's assessment of HCCI and do not believe it will be available for wide-scale application in the rulemaking timeframe, and therefore have not included it as a technology. HCCI technology has been in the research phase for several decades, and the only production applications to date use a highly-limited version that restricts HCCI combustion to a very narrow range of engine operating conditions.[372, 373, 374] Additional discussion of how Autonomie-modeled and non-modeled technologies are incorporated into the CAFE Model is located in [Section Translating Autonomie Results for Use in the CAFE Model], below.

ICCT and Meszler also commented that the agencies overly limited the availability of several technologies in the NPRM analysis. In response, the agencies reconsidered the restrictions that were applied in the NPRM analysis, and agree with the commenters for several technologies and technology classes. Many technologies identified by the commenters are now in production for the MY2017 as well as MY2018 and MY2019. We also think that the baseline fleet compliance data reflects adoption of many of these technologies. For the final rule analysis we have expanded the availability of several technologies. In the CAFE model, we are now allowing parallel hybrids (SHEVP2) to be adopted with high compression Atkinson mode engines (HCR0 and HCR1). In addition, as mentioned above, the Autonomie full-vehicle modeling included Variable Compression Ratio engine (VCR), Miller Cycle Engine (VTG), E-boost (VTGe) technologies, and cylinder deactivation technologies (DEAC) to be applied to turbocharged engines (TURBO1). As these changes relate to the technology effectiveness modeling, the analysis now includes effectiveness estimates based on full vehicle simulations for all of these combinations of technologies, that are then incorporated into the CAFE modeling.

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[371] ICCT also made the same request of EPA's ALPHA model, and the agencies' response to that comment is discussed in Section [xxx], below.

[372] Mazda introduced Skyactiv-X in Europe with a mild hybrid technology to assist the engine.

[373] Mazda News. "Revolutionary Mazda Skyactiv-X engine details confirmed as sales start," May 6, 2019. https://www.mazda-press.com/eu/news/2019/revolutionary-mazda-skyactiv-x-engine-details-confirmed-as-sales-start/. Last accessed Dec. 2, 2019.

[374] Confer. K. Kirwan, J. "Ultra Efficient Light-Duty Powertrain with Gasoline Low-Temperature Combustion." DOE Merit Review. June 9, 2017. https://www.energy.gov/sites/prod/files/2017/06/f34/aes094_confer_2017_o.pdf. Last accessed Dec. 2, 2019.

We disagree with comments stating the agencies should allow every technology to be available to every vehicle class.[375] Discussed earlier in this section, Autonomie models key aspects of vehicle operation that are most relevant to assessing fuel economy, vehicle performance and certain aspects of drivability (like EPA 2-cycle tests, EPA US06 cycle tests, gradability, low speed acceleration time from 0-to-60 mph, passing acceleration time from 50 to 80 mph, and number of transmission shifts). However, there are other critical aspects of vehicle functionality and operation that the agencies considered beyond those criteria, that cannot necessarily be reflected in the Autonomie modeling. For example, a pickup truck can be modeled with a continuously variable transmission (CVT) and show improvements on the 2-cycle tests. However, pickup trucks are designed to provide high load towing utility.[376] CVTs lack the torque levels needed to provide that towing utility, and would fail mechanically if subject to high load towing.[377] We provided discussions of some of these technical considerations in the PRIA, and explained why we had limited technologies for certain vehicle classes, such as limiting CVTs on pickups as in the example above. These and other limitations are discussed further in the individual technology sections.

The agencies also received a variety of comments that conflated aspects of the Autonomie models with technology inputs and input assumptions. For example, commenters expressed concern about the transmission gear set and final drive values used for the NPRM analysis, or more specifically, that the gear ratios were held constant across applications.[378] In this case, both the inputs (gear set and final drive ratio) and input assumption (ratios held constant) were discussed by the commenters. Because these comments are actually about technology inputs to the Autonomie model, for these and similar cases, the agencies are addressing the comments in the individual technology sections which discuss the technology inputs and input assumptions that impact the effectiveness values for those technologies.

Commented [A145]: **REVISE:** (for performance neutrality section) It's ok to address elsewhere, but the topic of adjusting final drive ratio for overall gearing should be (and is not currently) addressed in the performance neutrality section. Of secondary importance, the topic of gearing can be discussed elswere in the technology writeups.

For the NPRM analysis, the agencies prioritized using inputs that were based on data for identifiable technology configurations and that reflected practical real world constraints. The agencies provided detailed information on the NPRM analysis inputs and input assumptions in the NPRM Preamble, PRIA and ANL model documentation for engine technologies, transmission technologies, powertrain electrification, light-weighting, aerodynamic improvements, tire rolling resistance improvements, and other vehicle technologies. Comments and the agencies' assessment of comments for each technology are discussed in the individual technology sections below. Through careful consideration of the comments, the agencies have updated analytical inputs associated with several technologies, and as discussed above, have included several advanced technologies for which technical information was included in the NPRM. However, for most technologies, the agencies have determined that the technology inputs and input assumptions that were used in the NPRM analysis remain reasonable and the best available for the final rule analysis.

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[375] NHTSA-2018-0067-11723. NRDC Attachment2 at p. 4.
[376] SAE J2807. "Performance Requirements for Determining Tow-Vehicle Gross Combination Weight Rating and Trailer Weight Rating." Feb. 4, 2016.
[377] PRIA at p. 223 and 340.
[378] NHTSA-2018-0067-11873. Comments from Roush Industries, Attachment 1, at 14-15.
NHTSA-2018-0067-11873. Comments from CARB, at 110.

(2) How We Defined Different Vehicle Types in Autonomie

As described in the NPRM, ANL produced full-vehicle simulation modeling for many combinations of technologies, on many types of vehicles, but it did not simulate literally every single vehicle model/configuration in the analysis fleet because it would be impractical to assemble the requisite detailed information—much of which would likely only be provided on a confidential basis—specific to each vehicle model/configuration and because the scale of the simulation effort would correspondingly increase by orders of magnitude. Instead, ANL simulated 10 different vehicle types, corresponding to the five "technology classes" generally used in CAFE analysis over the past several rulemakings, each with two performance levels and corresponding vehicle technical specifications (e.g., small car, small performance car, pickup truck, performance pickup truck, etc.).

Technology classes are a means of specifying common technology input assumptions for vehicles that share similar characteristics. Because each vehicle technology class has unique characteristics, the effectiveness of technologies and combinations of technologies is different for each technology class. Conducting Autonomie simulations uniquely for each technology class provides a specific set of simulations and effectiveness data for each technology class. Like the Draft TAR analysis, there are separate technology classes for compact cars, midsize cars, small SUVs, large SUVs, and pickup trucks. However, new for the NPRM analysis and carried into this final rule analysis, each of those vehicle types has been split into "low" (or "standard") performance and a "high" performance versions, which represent two classes with similar body styles but different levels of performance attributes (for a total of 10 technology classes). The separate technology classes for high performance and low performance vehicles better account for performance diversity across the fleet.

~~The agencies~~As part of its contract with ANL, NHTSA directed ANL to develop a vehicle assumptions database to capture vehicle attributes that would comprise the full vehicle models. For each vehicle technology class, representative vehicle attributes and characteristics were identified from publicly available information and automotive benchmarking databases like A2Mac1,[379] ANL's Downloadable Dynamometer Database (D^3),[380] and EPA compliance and fuel economy data.[381] The resulting vehicle assumptions database consists of over 100 different attributes like vehicle frontal area, drag coefficient, fuel tank weight, transmission housing weight, transmission clutch weight, hybrid vehicle component weights, and weights for components that comprise engines and electric machines, tire rolling resistance, transmission gear ratios and final drive ratio. Each of the 10 different vehicle types was assigned a set of these baseline attributes and characteristics, to which combinations of fuel-saving technologies were added as inputs for the Autonomie simulations. For example, the characteristics of the MY 2016 Honda Fit were considered along with a wide range of other compact cars to identify

Commented [A146]: CHANGE AS SHOWN: "The agencies" is factually incorrect, because EPA had no hand in the ANL contract.

[379] A2Mac1: Automotive Benchmarking. (Proprietary data). Retrieved from https://a2mac1.com
[380] Downloadable Dynamometer Database (D^3). ANL Energy Systems Division. https://www.anl.gov/es/downloadable-dynamometer-database. Last accessed Oct. 31, 2019.
[381] Data on Cars used for Testing Fuel Economy. EPA Compliance and Fuel Economy Data. https://www.epa.gov/compliance-and-fuel-economy-data/data-cars-used-testing-fuel-economy. Last accessed Oct. 31, 2019.

representative characteristics for the Autonomie simulations for the base compact car technology class. The simulations determined the fuel economy achieved when applying each combination of technologies to that vehicle type, given its baseline characteristics.

For each vehicle technology class and for each vehicle attribute, ANL estimated the attribute value using statistical distribution analysis of publicly available data and data obtained from the A2Mac1 benchmarking database.[382] Some vehicle attributes were also based on test data and vehicle benchmarking, like the cold-start penalty for the FTP test cycle and vehicle electrical accessories load. The analysis of vehicle attributes used in the NPRM was discussed in the ANL model documentation,[383] and values for each vehicle technology class were provided with the NPRM for public review.[384]

The agencies did not believe it was appropriate to assign one single engine mass for each vehicle technology class in the NPRM analysis. To account for the difference in weight for different engine types, ANL performed a regression analysis of engine peak power versus weight, based on attribute data taken from the A2Mac1 benchmarking database. For example, to account for weight of different engine sizes like 4-cylinder versus 8-cylinder, ANL developed a relationship curve between peak power and engine weight based on the A2Mac1 benchmarking data. For the NPRM analysis, this relationship was used to estimate mass for all engine types regardless of technology type (e.g., variable valve lift and direct injection). Secondary weight reduction associated with changes in engine technology was applied by using this linear relationship between engine power and engine weight from the A2Mac1 benchmarking database. When a vehicle in the analysis fleet with an 8-cylinder engine adopted a more fuel efficient 6-cylinder engine, the total vehicle weight would reflect the updated engine weight with two less cylinders based on the peak power versus engine weight relationship. The impact of engine mass reduction on effectiveness is accounted for directly in the Autonomie simulation data through the application of the above relationship. Engine mass reduction via downsizing is, therefore, appropriately not included as part of vehicle mass reduction technology that is discussed in Section [Vehicle Mass Reduction] because doing so would result in double counting the impacts. As discussed further below, for the final rule we improved upon the precision of engine weights by creating two curves to separately represent naturally aspirated engine designs and turbocharged engine designs.

Commented [A147]: CHANGE AS SHOWN: Other engine mass reduction technologies involving material substitution are independent of downsizing and would appropriately be included separately

In addition, certain attributes were held at constant levels within each technology class to maintain vehicle functionality, performance and utility including noise, vibration, and harshness (NVH), safety, performance and other utilities important for customer satisfaction. For example, in addition to the vehicle performance constraints discussed in Section [Performance Neutrality],

[382] A2Mac1 is subscription-based benchmarking service that conducts vehicle and component teardown analyses. Annually, A2Mac1 removes individual components from production vehicles such as oil pans, electric machines, engines, transmissions, among the many other components. These components are weighed and documented for key specifications which is then available to their subscribers.

[383] NHTSA-2018-0067-0007, at 131. Islam, E., S, Moawad, A., Kim, N, Rousseau, A., "A Detailed Vehicle Simulation Process To Support CAFE Standards 04262018 – Report" ANL Autonomie Documentation. Aug 21, 2018.

[384] NHTSA-2018-0067-0003. ANL Autonomie Summary of Main Component Assumptions. Aug 21, 2018.

the analysis does not allow the frontal area of the vehicle to change, in order to maintain utility like ground clearance, head-room space, and cargo space, and a cold-start penalty is used to account for fuel economy degradation for heater performance and emissions system catalyst light-off.[385] This allows us to capture the discrete improvement in technology effectiveness while maintaining vehicle attributes that are important vehicle utility, consumer acceptance and compliance with criteria emission standards, and considering these constraints similar to how manufacturers do in the real world.

The agencies sought comment on the analytical approach used to determine vehicle attributes and characteristics for the Autonomie modeling. In response, we received a wide variety of comments on vehicle attributes ranging from discussions of performance increase from technology adoption (e.g. if a vehicle adopting an electrified powertrain improved its time to accelerate from 0-60 mph), to comments on vehicle attributes *not* modeled in Autonomie, like heated seats and cargo space.

Toyota and the Alliance commented that the inclusion of performance vehicle classes addressed the market reality that some consumers will purchase vehicles for their performance attributes and will accept the corresponding reduction in fuel economy. Furthermore, Toyota commented that some gain in performance is more realistic, and that "dedicating all powertrain improvements to fuel efficiency is inconsistent with market reality." Toyota "supports the agencies' inclusion of performance classes in compliance modeling where a subset of certain models is defined to have higher performance and a commensurate reduction in fuel efficiency."[386] Also, in support of the addition of performance vehicle classes, the Alliance commented that "vehicle categories have been increased to 10 to better recognize the range of 0–60 performance characteristics within each of the 5 previous categories, in recognition of the fact that many vehicles in the baseline fleet significantly exceeded the previously assumed 0–60 performance metrics. This provides better resolution of the baseline fleet and more accurate estimates of the benefits of technology."[387]

UCS commented that the CAFE model incorporates technology improvements to each vehicle by applying the effectiveness improvement of the average vehicle in the technology class, leading to discrete "stepped" effectiveness levels for technologies across the different vehicle types. UCS stated that in contrast, the OMEGA model takes into account a vehicle's performance characteristics through response-surface modeling based on relative deviation from the class average modeled in ALPHA.[388]

Although differences between the ALPHA and Autonomie models are discussed in more detail below, for the NPRM vehicle simulation analysis we expanded the number of vehicle classes from the five classes used in the Draft TAR to ten classes, to represent better the diversity of vehicle characteristics across the fleet. Each of these ten vehicle technology classes are

[385] The catalyst light-off is the temperature necessary to initiate the catalytic reaction and this energy is generated from engine.
[386] Toyota, Attachment 1, Docket No. NHTSA-2018-0067-12098, at 6.
[387] Alliance of Automobile Manufacturers, Attachment "Full Comment Set", Docket No. NHTSA-2018-0067-12073, at 135.
[388] NHTSA-2018-0067-12039, at p.24.

empirically built from benchmarking data and other information from various sources, amounting to hundreds of vehicle characteristics data points to develop each vehicle class. The agencies believe that the real-world data used to define vehicle characteristics for each of the ten vehicle classes, in addition to the ten vehicle technology classes themselves, ensures the analysis reasonably accounts for the diversity in vehicle characteristics across the fleet.

~~On the contrary, the vehicle models simulated in ALPHA and OMEGA consist of six vehicles that are defined by a road-load power requirement attribute (road-load coefficients) and power-to-weight ratio, which are generalized characteristics that attempt to represent the thousands of unique vehicles in the analysis fleet.[***] This approach would be ideal if the analysis fleet did not consist of so many different types of powertrains and body styles within each vehicle class. For example, the NPRM and final rule analyses include two pickup truck technology classes, one for high towing and payload capacity and one for lower capacity, whereas ALPHA/OMEGA only considers one full-size pickup truck class. Another example is small cars: the NPRM and final rule analyses have separate vehicle classes for a small car with a 2.4L DOHC naturally aspirated engine with greater vehicle size and higher rolling resistance tires (i.e., road-load characteristics) versus a small car with a 1.5 L Turbocharged engine with smaller vehicle size and lower rolling resistance tires. For the ALPHA/OMEGA analysis, these two would both fall in the same vehicle class and require an adjustment to align and better represent the vehicle characteristics. This limitation is the primary reason that a relative deviation adjustment is required by the OMEGA model using the surface-response model. Analysis with Autonomie effectiveness estimates and the CAFE model does not require these adjustments to effectiveness, because there are hundreds of characteristics to define the baseline vehicles that are defined by ten technology classes.~~

For the final rule analysis, we used the same process to obtain the vehicle attributes and characteristics for the vehicle technology classes. Data was acquired from publicly available sources, ANL D^3, EPA compliance and fuel economy data, and the A2mac1 benchmarking data. Accordingly, the attributes and characteristics of the modeled vehicles reflect actual vehicles that meet customer expectations and automakers' capabilities to manufacture the vehicles. In addition, for the final rule, we improved the NPRM analysis by updating some of the attribute values to account for changes in the fleet. For example, we have updated vehicle electrical accessory load on the test cycle to reflect higher electrical loads associated with contemporary vehicle features.

(3) How we Build Vehicle Models for Autonomie and Optimize Them for Simulation

Before any simulation is initiated in Autonomie, ANL must "build" a vehicle by assigning reference technologies and initial attributes to the components of the vehicle model

Commented [A148]: DELETE: This entire paragraph is factually incorrect, and in any case unnecessary to describe the FRM modeling. The CAFE model has FIVE vehicle types, with TWO modeled power/weight – roadload combinations within each type. In contrast, the ALPHA model has SIX vehicle types, and adjusts continuously within each type for any combination of power/weight – roadload [ref: SAE paper 2018-01-1273].

The remainder of the discussion here essentially argues that somehow two points are overall more representative and accurate of a complex space than a continuously variable surface.

Commented [A149]: DELETE: This example illustrates exactly the opposite point. Honda and GM are the only two manufacturers that offer the pair of engines described and in the FRM Market input file vehicles with both the 1.5L turbo and 2.4L NA engine are classified as "Small Performance Car". In contrast, the EPA approach [ref: SAE paper 2018-01-1273] would treat each vehicle diffently based on their unique power/weight and roadload levels.

Commented [A150]: DELETE: This depends on the interpretation of "require." NHTSA has **chosen** not to adjust the effectiveness, resulting in discete "stepped" effectiveness levels as noted by UCS. The resulting steps may or may not require adjustments, but this paragraph does not address the point, and is non-responsive to the comment made.

~~[***] Olechiw, M. EPA. "End-to-End Use of Alpha Vehicle Simulation in EPA's GHG Standards Assessment: From Baseline to Future Fleet." SAE Oil Meeting, January 25, 2018. https://www.epa.gov/sites/production/files/2018-10/documents/2018-sae-gmd-model-olechiw-2018-01.pdf. Last accessed Nov. 11, 2018.~~

representing each technology class.[390] The reference technologies are baseline technologies that represent the first step on each technology pathway used in the analysis. For example, a compact car is built by assigning it a baseline engine, a baseline 6-speed automatic transmission (AT6), a baseline level of aerodynamic improvement (AERO0), a baseline level of rolling resistance improvement (ROLL0), a baseline level of mass reduction technology (MR0), and corresponding attributes from the ANL vehicle assumptions database like individual component weights.[391] A baseline vehicle will have a unique starting point for the simulation and a unique set of assigned inputs and attributes, based on its technology class.

The next step in the process is to run a powertrain sizing algorithm that ensures the built vehicle meets or exceeds defined performance metrics, including low-speed acceleration (i.e., time required to accelerate from 0-60 mph), high-speed passing acceleration (time required to accelerate from 50-80 mph), gradeability (e.g. the ability of the vehicle to maintain constant 65 miles per hour speed on a six percent upgrade), and towing capacity. Together, these performance criteria are widely used by industry as metrics to quantify vehicle performance attributes that consumers observe and that are important for vehicle utility and customer satisfaction.

In the compact car example used above, we assigned an initial specific engine design and engine power, transmission, AERO, ROLL, and MR technologies, and other attributes like vehicle weight. If the built vehicle does not meet all the performance criteria in the first iteration, then the engine power is increased to meet the performance requirement. This increase in power is from higher engine displacement, which could involve an increase in number of cylinders, leading to an increase in the engine weight. The iterative process continues to check whether the compact car with updated engine power, and corresponding updated engine weight, meets its defined performance metrics. The loop stops once all the metrics are met, and at this point, a compact car technology class vehicle model becomes ready for simulation. For further discussion of the vehicle performance metrics, see Section [Performance Neutrality] and Section [Autonomie Engine Sizing].

Autonomie then adopts a single fuel saving technology to the baseline vehicle model, keeping everything else the same except for that one technology and the attributes associated with it. For example, the model would apply an 8-speed automatic transmission in place of the baseline 6-speed automatic transmission, which would lead to either an increase or decrease in the total weight of the vehicle based on the technology class assumptions. At this point, Autonomie confirms whether performance metrics are met for this new vehicle model through the previously discussed sizing algorithm. Once a technology has been assigned to the vehicle model and the resulting vehicle meets its performance metrics, those vehicle models will be used as inputs to the full vehicle simulations. So, in the example of the 6-speed to 8-speed automatic transmission technology update, we now have the initial ten vehicle models (one for each technology class), plus the ten new vehicle models with the updated 6-speed automatic

[390] For the NPRM analysis, chapter 8 Vehicle-Sizing Process in ANL model documentation had discussed this process in detail. For the final rule analysis, we will build upon this discussion of vehicle sizing process in ANL Model Documentation in Chapter 8 Vehicle-sizing process.
[391] [ANL Model assumptions and attribute file names]

transmission, which adds up to 20 different vehicle models for simulation. This permutation process is conducted for each of the over 50 technologies considered, and for all ten technology classes, which results in more than one million optimized vehicle models. Figure VI-4Figure VI-4 shows the process for building vehicles in Autonomie for simulation.

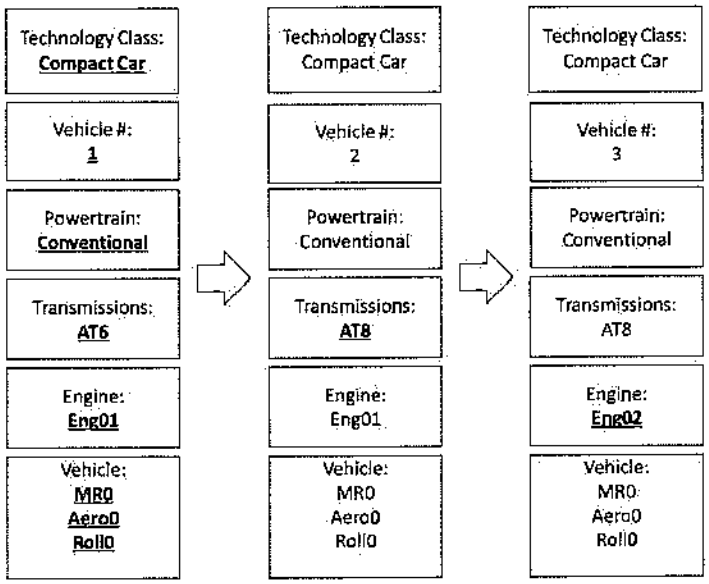

Figure VI-2 - Autonomie Technology Adoption Process for Vehicle building with compact car technology class as an example

Some of the technologies require extra steps for optimization before the vehicle models are built for simulation; for example, the sizing and optimization process is more complex for the electrified vehicles (i.e., HEVs, PHEVs) compared to vehicles with internal combustion engines, as discussed further, below. Throughout the vehicle building process, the following items are considered for optimization:

- Vehicle weight is decreased or increased in response to switching from one type of technology to another for the technologies for which we consider weight, such as different engine and transmission types;
- Vehicle performance is decreased or increased in response to the addition of mass reduction technologies when switching from one vehicle model to another vehicle model for the same engine;
- Vehicle performance is decreased or increased in response to the addition of a new technology when switching from one vehicle model to another vehicle model for the same hybrid electric machine; and

- Electric vehicle battery size is decreased or increased in response to the addition of mass, aero and/or tire rolling resistance technologies when switching from one vehicle model to another vehicle model.

Every time a vehicle adopts a new technology, the vehicle weight is updated to reflect the new component weight. For some technologies, the direct weight change is easy to assess. For example, in the NPRM we designated weights for transmissions so, when a vehicle is updated to a higher geared transmission, the weight of the original transmission is replaced with the corresponding transmission weight (e.g., the weight of a vehicle moving from a 5-speed automatic transmission to an 8-speed automatic transmission will be updated based on the 8-speed transmission weight).

For other technologies, like engine technologies, assessing the updated vehicle weight is much more complex. Discussed earlier, modeling a change in engine technology involves both the new technology adoption and a change in power (because the reduction in vehicle weight leads to lower engine loads, and a resized engine). When a new engine technology is adopted on a vehicle we account for the associated weight change to the vehicle based on the earlier discussed regression analysis of weight versus power. For the NPRM engine weight regression analysis, we considered 19 different engine technologies that consisted of unique components to achieve fuel economy improvements. This regression analysis is technology agnostic by taking the approach of using engine peak power versus engine weight because it removed biases to any specific engine technology in the analysis. Although we do not estimate the specific weight for each individual engine technology, such as VVT and SGDI, this process provides a reasonable estimate of the weight differences among engine technologies.

Figure Forthcoming
(awaiting gray scale version)

Figure VI-3 - Engine weight determination as function of power and type of air induction (naturality aspirated vs turbocharged)

For the final rule analysis, we used the same process to assign initial weights to the original 19 engines, plus the added engines. However, we improved upon precision of the weights by creating two separate curves separately to represent naturally aspirated engine designs and turbocharged engine designs.[392] This update resulted in two benefits. First, small naturally aspirated 4-cylinder engines that adopted turbocharging technology reflected the increased weight of associated components like ducting, clamps, the turbocharger itself, a charged air cooler, wiring, fasteners, and a modified exhaust manifold. Second, larger cylinder count engines like naturally aspirated 8-cylinder and 6-cylinder engines that adopted

[392] [ANL Final Model Documentation for final rule analysis Chapter 5.2.9 Engine Weight Determination.]

turbocharging and downsized technologies would have lower weight due to having fewer engine cylinders. For example, a naturally aspirated 8-cylinder engine that adopts turbocharging technology when downsized to a 6-cylinder turbocharged engine appropriately reflects the added weight of turbocharging components, and the lower weight of fewer cylinders.

As with conventional vehicle models, electrified vehicle models were built from the ground up. For the NPRM analysis, ANL used data from the A2mac1 database and vehicle test data to define different attributes like weights and power. ANL used one specific electric motor power for each type of hybrid and electric vehicle.[393] For MY2017, the U.S. market has an expanded number of available hybrid and electric vehicle models. To capture appropriately the improvements for electrified vehicles for the final rule analysis, the agencies applied the same regression analysis process that considers electric motor weight versus electric motor power for vehicle models that have adopted electric motors. Benchmarking data for hybrid and electric vehicles from the A2Mac1 database was analyzed to develop regression curve of electric motor peak power versus electric motor weight.[394]

(4) How Autonomie Sizes Powertrains for Full Vehicle Simulation

The agencies maintain performance neutrality of the full vehicle simulation analysis by resizing engines, electric machines, and hybrid electric vehicle battery packs at specific incremental technology steps. To address product complexity and economies of scale, engine resizing is limited to specific incremental technology changes that would typically be associated with a major vehicle or engine redesign.[395] Manufacturers have repeatedly told the agencies that the high costs for redesign and the increased manufacturing complexity that would result from resizing engines for small technology changes preclude them from doing so. It would be unreasonable and unaffordable to resize powertrains for every unique combination of technologies, and exceedingly so for every unique combination of technologies across every vehicle model due to the extreme manufacturing complexity that would be required to do so. The agencies reiterated in the NPRM that the analysis should not include engine resizing with the application of every technology or for combinations of technologies that drive small performance changes so that the analysis better reflects what is feasible for manufacturers.[396]

When a powertrain does need to be resized, Autonomie attempts to mimic manufacturers' development approaches to the extent possible. Discussed earlier, the Autonomie vehicle building process is initiated by building a baseline vehicle model with a baseline engine,

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[393] NHTSA-2018-0067-0005. ANL Autonomie Model Assumptions Summary. Aug 21, 2018. Non_Vehicle_Attributes tab. Specific power for PS and P2 HEVs were set to 2750 wh/ 2750, Plug-in HEVs were set to 375 watts/kg, and electric vehicles were set to 1400 watts/kg.

[394] [ANL Final Model Documentation for final rule analysis Chapter 5.2.10 Electric Machines System Weight.]

[395] *See* 83 FR 43027 (Aug. 24, 2018).

[396] For instance, a vehicle would not get a modestly bigger engine if the vehicle comes with floor mats, nor would the vehicle get a modestly smaller engine without floor mats. This example demonstrates small levels of mass reduction. If manufacturers resized engines for small changes, manufacturers would have dramatically more part complexity, potentially losing economies of scale.

transmission, and other baseline vehicle technologies. This baseline vehicle model (for each technology class) is sized to meet a specific set of performance criteria, including acceleration and gradeability.

The modeling also accounts for the industry practice of platform, engine, and transmission sharing to manage component complexity and the associated costs.[397] At a vehicle refresh cycle, a vehicle may inherit an already resized powertrain from another vehicle within the same engine-sharing platform that adopted the powertrain in an earlier model year. In the Autonomie modeling, when a new vehicle adopts fuel saving technologies that are inherited, the engine is not resized (the properties from the baseline reference vehicle are used directly and unchanged) and there may be a small change in vehicle performance. For example, in Figure VI-2
Figure VI-2, Vehicle 2 inherits Eng01 from Vehicle 1 while updating the transmission. Inheritance of the engine with new transmission may change performance. This example illustrates how manufacturers generally manage manufacturing complexity for engines, transmissions, and electrification technologies.

Autonomie implements different powertrain sizing algorithms depending on the type of powertrain being considered because different types of powertrains contain different components that must be optimized.[398] For example, the conventional powertrain resizing considers the reference power of the conventional engine (e.g., Eng01, a basic VVT engine, is rated at 108 kilowatts and this is the starting reference power for all technology classes) against the power-split hybrid (SHEVPS) resizing algorithm that must separately optimize engine power, battery size (energy and power), and electric motor power. An engine's reference power rating can either increase or decrease depending on the architecture, vehicle technology class, and whether it includes other advanced technologies.

Performance requirements also differ depending on the type of powertrain because vehicles with different powertrain types may need to meet different criteria. For example, a plug-in hybrid electric vehicle (PHEV) powertrain that is capable of traveling a certain number of miles on its battery energy alone (referred to as all-electric range, or AER, or as performing in electric-only mode) is also sized to ensure that it can meet the performance requirements of a US06 cycle in electric-only mode.

The powertrain sizing algorithm is an iterative process that attempts to optimize individual powertrain components at each step. For example, the sizing algorithm for conventional powertrains estimates required power to meet gradeability and acceleration performance and compares it to the reference engine power for the technology class. If the power required to meet gradeability and acceleration performance exceeds the reference engine

[397] Ford EcoBoost Engines are shared across ten different models in MY2019. https://www.ford.com/powertrains/ecoboost/. Last accessed Nov. 05, 2019.

[398] [ANL Model Documentation for Final Rule Analysis. Chapter 8.3.1 Conventional-Vehicle Sizing Algorithm.] [ANL Model Documentation for Final Rule Analysis. Chapter 8.3.2 Split-HEV Sizing Algorithm.] [ANL Model Documentation for the final rule Chapter 8.3.4 Blended PHEV sizing Algorithm]. [ANL Model Documentation for the final rule Chapter 8.3.5 Voltec PHEV (Extended Range) Vehicle Sizing Algorithm]. [ANL Model Documentation for final rule Chapter 8.3.6 BEV Sizing Algorithm]

power, the engine power is updated to the new value. Similarly, if the reference engine power exceeds the gradeability and acceleration performance power, it will be decreased to the lower power rating. As the change in power requires a change design of the engine, like increasing displacement (e.g., going from a 5.2-liter to 5.6-liter engine, or vice versa) or increasing cylinder count (e.g., going from an I4 to a V6 or vice versa), the engine weight will also change. The new engine power is used to update the weight of the engine.

Next, the conventional powertrain sizing algorithm enters an acceleration algorithm loop to verify low-speed acceleration performance (time it takes to go from 0 mph to 60 mph). In this step, Autonomie adjusts engine power to maintain a performance attribute for the given technology class and updates engine weight accordingly. Once the performance criteria are met, Autonomie ends the low-speed acceleration performance algorithm loop and enters a high-speed acceleration (time it takes to go from 50 mph to 80 mph) algorithm loop. Again, Autonomie might need to adjust engine power to maintain a performance attribute for the given technology, and it exits this loop once the performance criteria have been met. At this point, the sizing algorithm is complete for the conventional powertrain based on the designation for engine type, transmissions type, aero type, mass reduction technology and low rolling resistance technology. Figure VI-4Figure VI-4 below shows the sizing algorithm for conventional powertrains.

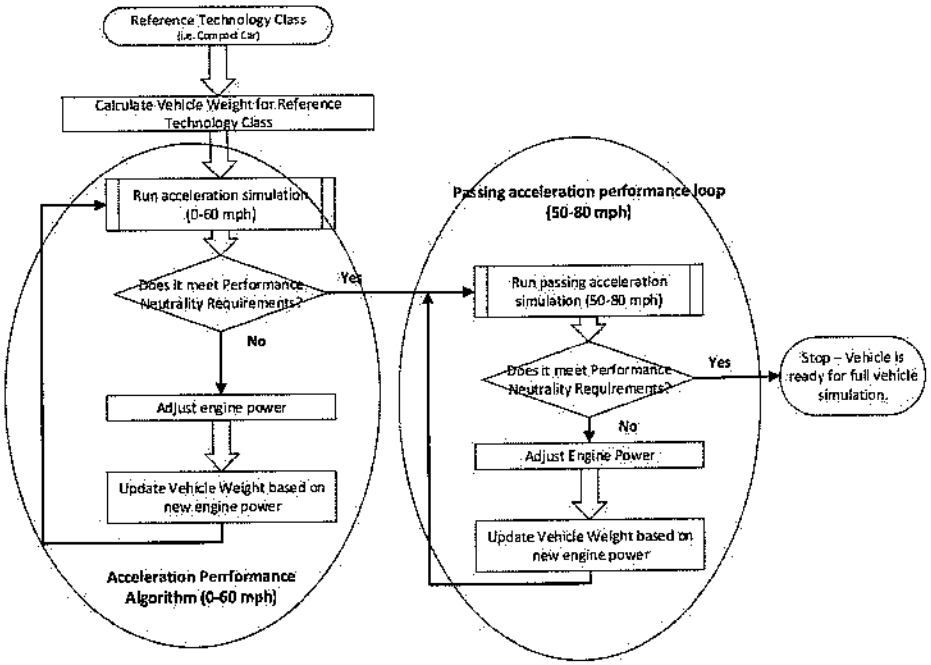

Figure VI-4 Conventional powertrain sizing algorithm

Depending on the type of powertrain considered, the sizing algorithms may also size to meet different performance criteria in different order. The powertrain sizing algorithms for electrified vehicles are considerably more complex, and are discussed in further detail in Section [Electrification], below.

(5) How We Considered Maintaining Vehicle Attributes

For this rulemaking analysis, consistent with past CAFE and CO_2 rulemakings, the agencies have analyzed technology pathways manufacturers could use for compliance that attempt to maintain vehicle attributes, utility, and performance. Using this approach allows the agencies to assess costs and benefits of potential standards under a scenario where consumers continue to get the similar vehicle attributes and features, other than changes in fuel economy. The purpose of constraining vehicle attributes is to simplify the analysis and reduce variance in other attributes that consumers value across the analyzed regulatory alternatives. This allows for a more streamlined accounting of costs and benefits by not requiring the values of other vehicle attributes that trade off with fuel economy.

~~Several examples of vehicle attributes, utility and performance that could be impacted by adoption of fuel economy improving technology include the following.~~

Commented [A151]: DELETE: This table is inconsistent with the technical analysis describe in this rule. Most of the attributes listed in this table were explicitly held constant (or in some cases improved) in ANL's technology simulation. What then, does "could be impacted" mean? Conventional ICE technologies, when implemented properly, have not been found by EPA to have a negative effect on consumer satisfaction. Even strong hybridization, which in some cases can result in a small reduction in cargo volume, often provides improved launch feel, passing acceleration, etc.

~~Table VI-15 – Vehicle Attributes that Could be Impacted by Fuel Economy Improving Technologies~~

~~Vehicle Attribute~~	~~Impacted by Fuel Economy Improving Technologies~~
~~Interior volume~~	~~Electrification, aerodynamics~~
~~Cargo/trunk space~~	~~Electrification, aerodynamics~~
~~Heater/defroster performance~~	~~Engine, transmission, start-stop~~
~~Air conditioning system performance~~	~~Air conditioning system, start-stop~~
~~Drivability~~	~~Engine, transmission~~
~~Idle quality~~	~~Engine, transmission~~
~~Noise~~	~~Engine, transmission, mass reduction~~
~~Vibration~~	~~Engine, transmission, mass reduction~~
~~Harshness~~	~~Engine, transmission, mass reduction, tires~~
~~Ride quality~~	~~Mass reduction, tires~~
~~Handling~~	~~Mass reduction, tires~~
~~Braking~~	~~Brake drag, tires~~
~~Steering feel~~	~~Electric power steering, tires~~
~~Turning circle~~	~~Footprint~~
~~0 – 60 mph acceleration~~	~~Engine, transmission, electrification, mass reduction, aero, tires~~
~~Passing acceleration~~	~~Engine, transmission, electrification, mass reduction, aero, tires~~
~~Gradeability~~	~~Engine, transmission, electrification, mass reduction, aero, tires~~

~~Towing capacity~~	~~Engine, transmission, electrification, mass reduction, aero~~
~~Launch acceleration feel~~	~~Engine, transmission, electrification, mass reduction~~
~~Styling~~	~~Aero, engine, transmission, electrification~~
~~Driving range~~	~~Electrification, fuel economy, tank size (mass)~~
~~Refueling time~~	~~Fuel economy, tank size~~

Consequences for the agencies not fully considering or accounting for potential changes in vehicle attributes, utility, and performance are degradation in vehicle attributes, utility, and performance that lead to consumer acceptance issues without accounting for the corresponding costs and/or not accounting for the costs of technology designs that maintain vehicle attributes, utility, and performance. ~~The agencies incorporated changes in the NPRM analysis and that are carried into this final rule that address deficiencies in past analyses, including the Draft TAR and Proposed Determination analyses. These changes were discussed in the NPRM and are repeated in the discussion of individual technologies in this Preamble, the FRIA, and supporting documents. The following are several examples of technologies that did not maintain vehicle attributes, utility, and performance in the Draft TAR and Proposed Determination analyses.~~

~~For the EPA Draft TAR and Proposed Determination analyses, HCR engine and downsized and turbocharged engine technologies effectiveness was estimated using Tier 2 certification fuel, which has a higher octane rating compared to regular octane fuel.[200], [201] This does not maintain functionality because consumers would incur higher costs for using premium fuel in order to achieve the modeled fuel economy improvements, compared to baseline engines that were replaced, which operated on lower cost regular octane fuel. By not maintaining the fuel octane functionality and vehicle attributes, the EPA Draft TAR and Proposed Determination analyses applied higher effectiveness for these technologies than could be achieved had regular octane fuel been assumed for the HCR and downsized turbocharged engines. The Draft TAR and Proposed Determination analyses also did not account for the higher costs that would be incurred by consumers to pay for high octane fuel. These issues were addressed in the NPRM and this final rule analysis, and account for some of the effectiveness and cost differences between the Draft TAR Proposed Determination and the NPRM final rule.[202]~~

~~Another example is mass reduction technology. As background, the agencies characterize mass reduction as either primary mass reduction or secondary mass reduction. Primary mass reduction involves reducing mass of components that can be done independently of the mass of other components. For example, the mass of a hood (e.g., replacing a steel hood with an aluminum hood) or reducing the mass of a seat are examples of primary mass reduction because each can be implemented independently. When there is a significant level of primary mass reduction, other components that are designed based on the mass of primary components, may be redesigned and have lower mass. An example of secondary mass reduction is the brake system. If the mass of primary components is reduced sufficiently, the resulting lighter weight~~

Commented [A152]: DELETE: These following paragraphs should be removed, both as not representative of EPA's prior work, and unnecessary for the support of the FRM analysis. EPA does not agree that EPA's own Draft TAR and Proposed Determination analysis were not appropriately representative of an overall performance neutral assumption.

Specifically, for fuel assumptions, EPA's engine maps were based on extensive vehicle chassis dynamometer testing on both Tier 2 and Tier 3 fuels, and as a result reflect both performance neutral operation on regular octane fuel as well as appropriate GHG performance on certification fuel.

For engine resizing assumptions, EPA's modeling is designed to assign technology effectiveness values which maintain, on average, performance of the vehicles to which those technologies are applied. This is no different than the Autonomie/CAFE model's use of a constant effectiveness value for all vehicles within a vehicle type. A uniform effectiveness value is a simplifying modeling assumption, since to actually achieve the same effectiveness for vehicles which vary in power and performance, a unique engine size would be required. One should not conclude, however, that the model is meant to represent an infinite complexity of engine sizes. Instead, the effectiveness numbers represent the average value over a range of engine sizes. As long as the effectiveness number is not biased high or low, and is applied to reasonably narrow vehicle type definition, a uniform effectiveness assumption is a reasonable modeling simplification.

Commented [A153]: DELETE: Two-cycle certification is not the same as on-road operation. Whatever the argument for using Tier 2 v. Tier 3 to determine regulatory numbers, no one's suggesting consumers use cert fuel for daily driving, so this statement appears to come from way out in left field.

[200] ~~Tier 2 fuel has an octane rating of 93. Typical regular grade fuel has an octane rating of 87 (R+M)/2 octane~~
[201] ~~EPA Proposed Determination at 2-209 to 2-212~~
[202] ~~For more details, see Section II supra.~~

~~vehicle could maintain braking performance and attributes, and safety with a lighter weight brake system. Mass reduction in the brake system is secondary mass reduction because it requires primary mass reduction before it can be incorporated. For the EPA Draft TAR and Proposed Determination analyses, **secondary mass reduction was applied exclusively based on cost,** with no regard to whether sufficient primary mass reduction was applied concurrently. The analyses did not account for the degraded functionality of the secondary components and systems and also understated the costs for lower levels of mass reduction.[xx] These issues were addressed in the NPRM and this final rule analysis, and account for some of the cost differences between the Draft TAR Proposed Determination and the NPRM final rule.~~

~~The agencies note that for some technologies it is not reasonable or practicable to match exactly the baseline vehicle's attributes, utility, and performance. For example, when engines are resized to maintain acceleration performance, if the agencies applied a criterion that allowed no shift in performance whatsoever, there would be an extreme proliferation of unique engine displacements. Manufacturers have repeatedly and consistently told the agencies that the high costs for redesign and the increased manufacturing complexity that would result from resizing engines for small technology changes preclude them from doing so. It would be unreasonable and unaffordable to resize powertrains for every unique combination of technologies, and exceedingly so for every unique combination technologies across every vehicle model due to the extreme manufacturing complexity that would be required to do so.[xx] For the NPRM and final rule analyses, engine resizing is limited to specific incremental technology changes that would typically be associated with a major vehicle or engine redesign to address product complexity and economies of scale considerations. The EPA Draft TAR and Proposed Determination analyses adjusted the effectiveness of every technology combination assuming performance could be held constant for every combination, and **the analysis did not recognize or account for the extreme complexity nor the associated costs for that impractical assumption.** The NPRM and final rule analyses account for these real-world practicalities and constraints, and doing so explains some of the effectiveness and cost differences between the Draft TAR Proposed Determination and the NPRM final rule.~~

The subsections for individual technologies discuss the technology assumptions and constraints that were considered to maintain vehicle attributes, utility, and performance as closely as possible. The agencies believe that any minimal remaining differences, which may directionally either improve or degrade vehicle attributes, utility and performance are small enough to have *de minimus* impact on the analysis.

(6) How We Considered Performance Neutrality

The CAFE model examines technologies that can improve fuel economy and reduce CO_2 emissions. An improvement in efficiency can be realized by improving the powertrain that propels the vehicle (e.g., replacing a 6-cylinder engine with a smaller, turbocharged 4-cylinder engine), or by reducing the vehicle's loads or burdens (e.g., lowering aerodynamic drag, reducing vehicle mass and/or rolling resistance). Either way, these changes reduce energy

Commented [A154]: DELETE: This is factually incorrect, and does not represent the mass reduction analysis used by EPA previously.

Commented [A155]: DELETE: See comment above. Neither EPA nor NHTSA's prior/current analyses ever claimed to identify the specific engine displacement of each vehicle into the future. Instead, assumptions about engine resizing are inherently incorporated into the technology cost and effectiveness assumptions.

NHTSA is apparently making the argument here that applying uniform effectiveness values to vehicles with varying attributes is preferable to applying varying effectiveness values. That position is debateable, but as long as the overall effectiveness value is not biased high or low, and remains within a reasonably narrow band, either modeling approach would be defensible.

Commented [A156]: REVISE: Main recommendation here is to add the citation for the docketed Autonomie performance simulation results, and confirm consistency between those results and the text conclusions. EPA cannot provide detailed comments on this section without having reviewed the updated performance results from Autonomie for this FRM analysis.

~~[xx] For more details, see Section [Mass Reduction]~~

~~[xx] For more details, see Section [Performance Neutrality]~~

consumption and create a range of choices for automobile manufacturers. At the two ends of the range, the manufacturer can choose either:

A) *To design a vehicle that does same the amount of work as before but uses less fuel.*

For example, a redesigned pickup truck would receive a turbocharged V6 engine in place of the outgoing V8. The pickup would offer no additional towing capacity, acceleration, larger wheels and tires, expanded infotainment packages, or customer convenience features, but would achieve a higher fuel economy rating (and correspondingly lower CO_2 emissions).

B) *To design a vehicle that does more work and uses the same amount of fuel as before.*

For example, a redesigned pickup truck would receive a turbocharged V6 engine in place of the outgoing V8, but with engine efficiency improvements that allow the same amount of fuel to do more work. The pickup would offer improved towing capacity, improved acceleration, larger wheels and tires, an expanded (heavier) infotainment package, and more convenience features, while maintaining (not improving) the fuel economy rating of the previous year's model.

In other words, automakers weigh the trade-offs between vehicle performance/utility and fuel economy, and they choose a blend of these attributes to balance meeting fuel economy and emissions standards and suiting the demands of their customers.

Historically, vehicle performance has improved over the years. The average horsepower is the highest that it has ever been; all vehicle types have improved horsepower by at least 49% compared to the 1975 model year, and pickup trucks have improved by 141%.[404] Since 1978, the 0-60 acceleration time of vehicles has improved by 39-47% depending on vehicle type.[405] Also, to gain consumer acceptance of downsized turbocharged engines, manufacturers have stated they often offer an *increase* in performance.[406] Fuel economy has also improved, but the horsepower and acceleration trends show that not 100% of technological improvements have been applied to fuel savings. While future trends are uncertain, the past trends suggest vehicle performance is unlikely to *decrease*, as it seems reasonable to assume that customers will at a minimum demand vehicles that offer the same utility as today's fleet.

For this rulemaking analysis, consistent with past CAFE and CO_2 rulemakings, the agencies have analyzed technology pathways manufacturers could use for compliance that attempt to maintain vehicle attributes, utility and performance. NHTSA's analysis in the Draft TAR used the same approach for performance neutrality as was used for the NPRM and is being

[404] The 2018 EPA Automotive Trends Report (EPA-420-R-19-002 March 2019) https://www.epa.gov/automotive-trends/download-automotive-trends-report.

[405] *The 2018 EPA Automotive Trends Report* (EPA-420-R-19-002 March 2019) https://www.epa.gov/automotive-trends/download-automotive-trends-report.

[406] Alliance of Automobile Manufacturers, Attachment "Comment", Docket No. EPA-HQ-OAR-2015-0827-4089, at 122.

carried into this final rule. This approach is described throughout this section and further in FRIA Chapter [xxx]. ~~For the Draft TAR and Proposed Determination, the EPA analyses used an approach that maintained 0-60 mph acceleration time for every technology package. However, that approach did not account for the added development, manufacturing, assembly and service parts complexity and associated costs that would be incurred by manufacturers to produce the substantial number of engine variants that would be required to achieve those CO_2 improvements.[407]~~ Using the NPRM approach, which is carried into this final rule, allows the agencies to assess costs and benefits of potential standards under a scenario where consumers continue to get the same vehicle attributes and features, other than changes in fuel economy (approaching the scenario in example "A" above). This approach also eliminates the need to assess the value of changes in vehicle attributes and features. As discussed later in this section, while some small level of performance increase is unavoidable when conducting this type of analysis, the added technology results almost exclusively in improved fuel economy. This allows the cost of these technologies to reflect almost entirely the cost of compliance with standards with nearly neutral vehicle performance.

Commented [A157]: DELETE: This reference to investment costs and engine variants is the topic of a long-standing discussion and difference of opinion between the agencies. It's unlikely to be resolved here, and in any case is not necessary for the main point of the paragraph, which is that both agengies agree that it is appropriate to attempt to maintain utility across technology packages.

The CAFE model maintains the initial performance and utility levels of the analysis vehicle fleet, while considering real world constraints faced by manufacturers.

To maintain performance neutrality when applying fuel economy technologies, it is first necessary to characterize the performance levels of each of the nearly 3000 vehicle models in the MY 2017 baseline fleet. As discussed in Section [Technology Class], above, each individual vehicle model in the analysis fleet was assigned to one of ten vehicle "technology classes"— the class that is most similar to the vehicle model. The technology classes include five standard class vehicles (compact car, midsize car, small SUV, midsize SUV, pickup) plus five "performance" versions of these same body styles.[408] Each vehicle class has a unique set of attributes and characteristics, including vehicle performance metrics, that describe the typical characteristics of the vehicles in that class.

The analysis used four criteria to characterize vehicle performance attributes and utility:

- Low-speed acceleration (time required to accelerate from 0-60 mph)
- High-speed acceleration (time required to accelerate from 50-80 mph)
- Gradeability (the ability of the vehicle to maintain constant 65 miles per hour speed on a six percent upgrade)
- Towing capacity

Low-speed and high-speed acceleration target times are typical of current production vehicles and range from 6 to 10 seconds depending on the vehicle class; for example, the midsize SUV performance class has a low- and high-speed acceleration target of 7 seconds.[409] The gradeability criterion requires that the vehicle, given its attributes of weight, engine power, and

~~[407] Each variant would require a unique engine displacement, requiring unique internal engine components, such as crankshaft, connecting rods and others.~~

[408] Separate technology classes were created for high performance and low performance vehicles to better account for performance diversity across the fleet.

[409] Note, for all vehicle classes, the low and high-speed acceleration targets use the same value.

transmission gearing, be capable of maintaining a minimum of 65 mph while going up a six percent grade. The towing criterion, which is applicable only to the pickup truck and performance pickup truck vehicle technology classes, is the same as the gradeability requirement but adds an additional payload/towing mass (3000 lbs for pickups, or 4350 lbs for performance pickups) to the vehicle, essentially making the vehicle heavier.

In addition, to maintain the capabilities of certain electrified vehicles in the 2017 baseline fleet, the analysis required that those vehicles be capable of achieving the accelerations and speeds of certain standard driving cycles. The agencies use the US06 "aggressive driving" cycle and the UDDS "city driving" cycle to ensure that core capabilities of BEVs and PHEVs, such as driving certain speeds and/or distances in electric-only mode, are maintained. In addition to the four criteria discussed above, the following performance criteria are applied to these electrified vehicles:

- Battery electric vehicles (BEV) are sized to be capable of completing the US06 "aggressive driving" cycle.
- Plug-in hybrid vehicles with 50 mile all-electric range (PHEV50) are sized to be capable of completing the US06 "aggressive driving" cycle in electric-only mode.
- Plug-in hybrid vehicles with 20 mile all-electric range (PHEV20) are sized to be capable of completing the UDDS "city driving" cycle in electric-only (charge depleting) mode.[410]

Together, these performance criteria are widely used by industry as metrics to quantify vehicle performance attributes that consumers observe and that are important for vehicle utility and customer satisfaction.[411]

When certain fuel-saving technologies are applied that affect vehicle performance to a significant extent, such as replacing a pickup truck's V8 engine with a turbocharged V6 engine, iterative resizing of the vehicle powertrain (engine, electric motors, and/or battery) is performed in the Autonomie simulation such that the above performance criteria is maintained. For example, if the aforementioned engine replacement caused an improvement in acceleration, the engine may be iteratively resized until vehicle acceleration performance is shifted back to the initial target time for that vehicle technology class. For the low and high-speed acceleration criteria, engine resizing iterations continued until the acceleration time was within plus or minus

[410] PHEV20's are blended-type plug-in hybrid vehicles, which are capable of completing the UDDS cycle in charge depleting mode without assistance from the engine. However, under higher loads, this charge depleting mode may use supplemental power from the engine.

[411] Conlon, B., Blohm, T., Harpster, M., Holmes, A. et al., "The Next Generation "Voltec" Extended Range EV Propulsion System," SAE Int. J. Alt. Power. 4(2):2015, doi:10.4271/2015-01-1152. Kapadia, J., Kok, D., Jennings, M., Kuang, M., et al., "Powersplit or Parallel - Selecting the Right Hybrid Architecture," SAE Int. J. Alt. Power. 6(1):2017, doi:10.4271/2017-01-1154. Islam, E., A. Moawad, N. Kim, and A. Rousseau, 2018a, An Extensive Study on Vehicle Sizing, Energy Consumption and Cost of Advance Vehicle Technologies, Report No. ANL/ESD-17/17, Argonne National Laboratory, Lemont, Ill., Oct 2018.

0.2 seconds of the target time,[412, 413] which is judged to balance reasonably the precision of engine resizing with the number of simulation iterations needed to achieve performance within the 0.2 second window, and the associated computer resources and time required to perform the iterative simulations. Engine resizing is explained further in Section [Autonomie Engine Resizing] and the [FRM ANL Model Documentation].

The Autonomie simulation resizes until the least capable of the performance criteria is met, to ensure the pathways do not degrade any of the vehicle performance metrics. It is possible that as one criterion target is reached after the application of a specific technology or technology package, other criteria may be better than their target values. For example, if the engine size is decreased until the low speed acceleration target is just met, it is possible that the resulting engine size would cause high speed acceleration performance to be better than its target.[414] Or, a PHEV50 may have an electric motor and battery appropriately sized to operate in all electric mode through the repeated accelerations and high speeds in the US06 driving cycle, but the resulting motor and battery size enables the PHEV50 slightly to over-perform in 0-60 acceleration, which utilizes the power of both the electric motor and combustion engine.

To address product complexity and economies of scale, engine resizing is limited to specific incremental technology changes that would typically be associated with a major vehicle or engine redesign.[415] Manufacturers have repeatedly and consistently told the agencies that the high costs for redesign and the increased manufacturing complexity that would result from resizing engines for small technology changes preclude them from doing so. It would be unreasonable and unaffordable to resize powertrains for every unique combination of technologies, and exceedingly so for every unique combination technologies across every vehicle model due to the extreme manufacturing complexity that would be required to do so. Engine displacements are further described in Section [Engine Displacements].

To address this issue, and consistent with past rulemakings, the NPRM simulation allowed engine resizing when mass reductions of 7.1%, 10.7%, 14.2% (and 20% for the final rule analysis) were applied to the vehicle curb weight,[416] and when one powertrain architecture was replaced with another architecture during a redesign cycle.[417] At its refresh cycle, a vehicle

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[412] For example, if a vehicle has a target 0-60 acceleration time of 6 seconds, a time within 5.8-6.2 seconds was accepted.

[413] With the exception of a few performance electrified vehicle types which, based on observations in the marketplace, use different criteria to maintain vehicle performance without battery assist. Performance PHEV20, and Performance PHEV50 resize to the performance of a conventional six-speed automatic (CONV 6AU). Performance SHEVP2, engines/electric-motors were resized if the 0-60 acceleration time was worse than the target, but not resized if the acceleration time was better than the target time.

[414] The Autonomie simulation databases include all of the estimated performance metrics for each combination of technology as modeled.

[415] *See* 83 FR 43027 (Aug. 24, 2018).

[416] These correspond, respectively, to reductions of 10%, 15%, 20%, and 28.2% of the vehicle glider mass. For more detail on glider mass calculation, see section [xxx].

[417] Some engine and accessory technologies may be added to an engine without an engine architecture change. For instance, manufacturers may adapt, but not replace engine architectures to include cylinder deactivation, variable valve lift, belt-integrated starter generators, and other basic technologies. However, switching from a naturally

may also inherit an already resized powertrain from another vehicle within the same engine-sharing platform. The analysis did not re-size the engine in response to adding technologies that have smaller effects on vehicle performance. For instance, if a vehicle's curb weight is reduced by 3.6% (MR1), causing the 0-60 mile per hour time to improve slightly, the analysis would not resize the engine. The criteria for resizing used for the analysis better reflects what is feasible for manufacturers to do.[418]

Automotive manufacturers have commented that the CAFE model's consideration of the constraints faced in relation to vehicle performance and economies of scale are realistic.

Industry associations and individual manufacturers widely supported the use of the performance metrics used in the NPRM analysis, the use of standard and higher performance technology classes, and the representation in the analysis of the real-world manufacturing complexity constraints and criteria for powertrain redesign.

The Alliance of Automobile Manufacturers (Alliance), Ford, and Toyota stated that the inclusion of additional performance metrics such as gradeability are appropriate. Specifically in support of the gradeability performance criteria, the Alliance commented that "performance metrics related to vehicle operation in top gear are just as critical to customer acceptance as are performance metrics such as 0-60 mph times that focus on performance in low-gear ranges."[419] The Alliance also commented specifically on the relationship between gradeability and downsized engines, stating that as "engine downsizing levels increase, top-gear gradeability becomes more and more important," and further that the consideration of gradeability "helps prevent the inclusion of small displacement engines that are not commercially viable and that would artificially inflate fuel savings."[420]

Ford and Toyota similarly commented in support of the CAFE model's consideration of multiple performance criteria. Ford stated that this model "takes a more realistic approach to performance modeling" and "better replicates OEM attribute-balancing practices." Ford stated furthermore that "OEMs must ensure that each individual performance measure – and not an overall average – meets its customer's requirements," and that, in contrast, previous analyses did "not align with product planning realities."[421] Toyota commented in support of including

aspirated engine to a turbo-downsized engine is an engine architecture change typically associated with a major redesign and radical change in engine displacement.

[418] For instance, a vehicle would not get a modestly bigger engine if the vehicle comes with floor mats, nor would the vehicle get a modestly smaller engine without floor mats. This example demonstrates small levels of mass reduction. If manufacturers resized engines for small changes, manufacturers would have dramatically more part complexity, potentially losing economies of scale.

[419] Alliance of Automobile Manufacturers, Attachment "Full Comment Set," Docket No. NHTSA-2018-0067-12073, at 139.

[420] Alliance of Automobile Manufacturers, Attachment "Full Comment Set," Docket No. NHTSA-2018-0067-12073, at 135.

[421] Ford, Attachment 1, Docket No. NHTSA-2018-0067-11928, at 8.

gradeability as a performance metric "to avoid underpowered engines and overestimated fuel savings."[422]

Toyota and the Alliance commented that the inclusion of performance vehicle classes addressed the market reality that some consumers will purchase vehicles for their performance attributes and will accept the corresponding reduction in fuel economy. Furthermore, Toyota commented that most consumers consider more than just fuel economy when purchasing a vehicle, and that "dedicating all powertrain improvements to fuel efficiency is inconsistent with market reality." Toyota "supports the agencies' inclusion of performance classes in compliance modeling where a subset of certain models is defined to have higher performance and a commensurate reduction in fuel efficiency."[423] Also in support of the addition of performance vehicle classes, the Alliance commented that "vehicle categories have been increased to 10 to better recognize the range of 0–60 performance characteristics within each of the 5 previous categories, in recognition of the fact that many vehicles in the baseline fleet significantly exceeded the previously assumed 0–60 performance metrics. This provides better resolution of the baseline fleet and more accurate estimates of the benefits of technology."[424]

Toyota also commented in support of various real-world manufacturing complexity constraints employed in the analysis for powertrain redesigns. Toyota commented that model parameters such as redesign cycles and engine sharing across vehicle models place a more realistic limit on the number of engines and transmissions that a manufacturer is capable of introducing. Toyota also commented in support of the constraints that the CAFE model placed on engine resizing, stating that "there are now more realistic limits placed on the number of engines and transmissions in a powertrain portfolio which better recognizes [how] manufacturers must manage limited engineering resources and control supplier, production, and service costs. Technology sharing and inheritance between vehicle models tends to limit the rate of improvement in a manufacturer's fleet." Toyota pointed out that this is in contrast to previous analyses in which resizing was too unconstrained, which created an "unmanageable number of engine configurations within a vehicle platform" and spawned cases where "engine downsizing and power reduction sometimes exceeded limits beyond basic acceleration requirements needed for vehicle safety and customer satisfaction."[425]

The above comments from the Alliance, Ford, and Toyota support the methodologies the agencies employed to conduct a performance neutral analysis. These methodologies helped to ensure that multiple performance criteria, including gradeability, are all individually accounted for and maintained when a vehicle powertrain is resized, and that real-world manufacturing complexity constraints are factored in to the agencies' analysis of feasible pathways manufacturers could take to achieve compliance with CAFE standards. The agencies continue to believe this is a reasonable approach for the aforementioned reasons.

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[422] Toyota, Attachment 1, Docket No. NHTSA-2018-0067-12098, at 6.
[423] Toyota, Attachment 1, Docket No. NHTSA-2018-0067-12098, at 6.
[424] Alliance of Automobile Manufacturers, Attachment "Full Comment Set", Docket No. NHTSA-2018-0067-12073, at 135.
[425] Toyota, Attachment 1, Docket No. NHTSA-2018-0067-12098, at 6.

Environmental advacacy groups and CARB criticized the CAFE model's engine resizing constraints and how they affected the acceleration performance criteria.

CARB, The International Council on Clean Transportation (ICCT), the Union of Concerned Scientists (UCS), and the American Council for an Energy-Efficient Economy (ACEEE) commented that the CAFE model was not performance neutral, allowing an improvement in performance which reduced the effectiveness of applied fuel-saving technologies and/or increased the cost of compliance. Specifically, ACEEE stated that there appeared to be a shortfall in the fuel economy effectiveness of technology packages, potentially resulting from the effectiveness being "consumed" by additional vehicle performance rather than improvement of fuel economy. Several of these same commenters conducted analyses attempting to quantify the magnitude of these changes in vehicle performance for various vehicle technology classes.

CARB commented on the performance shift of several vehicle types. Analyzing the 0-60 acceleration for the medium car non-performance technology class and looking at all cases with resized engines, CARB claimed that "effectively half of the simulations resulted in improved performance."[426] Focusing on electrified vehicles in that same technology class, CARB stated that "the data from the ANL simulations shows that 76 of the 88 strong electrified packages (including P2HPV, SHEVPS, BEV, FCEV, PHEV), where ANL purposely resized the system to maintain performance neutrality, resulted in notably faster 0 to 60 mph acceleration times and passing times." Specifically regarding parallel hybrid electric vehicles (SHEVP2), CARB stated that all modeled packages resulted in improved performance.[427] UCS commented that the NPRM analysis allowed too much change in vehicle performance, stating that "while some performance creep may be reasonable" many performance values show "an overlap between performance and non-performance vehicles" within the compact car technology class.[428]

The agencies carefully considered these comments. For the NPRM analysis, the SHEVP2 engines/electric-motors were resized if the 0-60 acceleration time was worse than the target, but not resized if the acceleration time was better than the target. This approach maintained vehicle performance with a depleted battery (without electric assist) in order to maintain fully the performance and utility characteristics under all conditions, and improved performance when electric assist was available (when the battery is not depleted), such as during the 0-60 mph acceleration. The agencies found that this resulted in some parallel hybrid vehicles having improved 0-60 acceleration times. This approach was initially chosen for the NPRM because the resulting level of improved performance was consistent with observations of how industry had applied SHEVP2 technology. However, in assessing the CARB comment, the agencies balanced the NPRM approach for SHEVP2 performance with the agencies' criteria of

[426] California Air Resources Board, Attachment 2, Docket No. NHTSA-2018-0067-11873, at 180. Note that the target acceleration time for medium car non-performance is in fact 9.0 seconds, as indicated in ANL documentation, but was incorrectly reported as 9.4s in NPRM table II-7 in the NPRM.
[427] California Air Resources Board, Attachment 2, Docket No. NHTSA-2018-0067-11873, at 186.
[428] Union of Concerned Scientists, Attachment 2, Docket No. NHTSA-2018-0067- 12039, at 24.

maintaining vehicle functionality and performance when technology is applied. Both could not be fully achieved under all conditions for the case of the SHEVP2.

The agencies concluded it is reasonable to maintain performance including electric assist when SHEVP2 technology is applied to a standard (non-performance) vehicle, and therefore the analysis for the final rule allows upsizing *and* downsizing of the parallel hybrid powertrain (SHEVP2) using the 0.2 seconds window around the target.[429] For performance vehicles, the agencies concluded that it remains reasonable to maintain vehicle performance with a depleted battery (without electric assist) in order to maintain fully the performance characteristics under all conditions, and continued to use the NPRM methodology.

The refinement for the standard performance SHEVP2 resolved the electrified packages issue identified by CARB, and also addressed most of the change in performance in the overall fleet, including with compact cars as mentioned by UCS. As explained further below, the agencies assessed performance among the alternatives for the final rule analysis. That assessment showed that, with the final rule refinements, 245 out of 255 total resized vehicles (96 percent of vehicles) in the medium non-performance class (same class focused on by CARB), had 0-60 mph acceleration times within the plus-or-minus 0.2 second window (8.8 to 9.2 seconds).[430] The only vehicles outside the window were certain strong electrified vehicles which exceeded 0-60 the acceleration target as a result of achieving other performance criteria, such as the US06 driving cycles in all-electric-mode.[431]

The assessment also showed that for the small car class (mentioned by UCS) the acceleration times of performance and non-performance vehicles do not go beyond each other's targets. For example, the vehicle in the small car class with the very best 0-60 mph time and a conventional powertrain achieves an 8.38 second 0-60 mph time, which is slower than the performance small car baseline of 8 seconds. This vehicle had multiple incremental technologies applied, including for example aerodynamic improvements, and has not reached the threshold for engine resizing.[432] After engine resizing, the "fastest" conventional small car has a 0-60 mph time of 9.9 seconds, only 0.1 seconds from the target of 10 seconds.[433]

CARB also commented on the improvement of "passing times," or 50-80 mph high-speed acceleration times. As stated above, an improvement in one or more of the performance criteria is an expected outcome when using the rulemaking analysis methodology that resizes powertrains such that there is no degradation in any of the performance metrics. Consistent with past rulemakings, the agencies do not believe it is appropriate for the rulemaking analysis to show pathways that degrade vehicle performance or utility for one or more of the performance criteria, as doing so would adversely impact functional capability of the vehicle and could lead to

[429] [Insert reference to Autonomie model documentation describing resizing targets]. To represent marketplace trends better, the performance class of SHEVP2's allow acceleration time below 0.2 seconds less than the target, and PHEV20's and PHEV50's inherit combustion engine size from the conventional powertrain they are replacing.
[430] This includes 135 strong electrified vehicles.
[431] As noted earlier, electrified vehicles had to be capable of successfully completing UDDS or US06 driving cycles in all-electric mode, and in some cases the resulting motor size produced improved acceleration times.
[432] [insert reference to tech section describing resizing logic].
[433] [insert reference to ANL database file for Small cars].

customer dissatisfaction. The agencies agree there is very small increase in passing performance for some technology combinations, and believe this is an appropriate outcome. High-speed acceleration is rarely the least-capable performance criteria.

CARB, ICCT, UCS, and H-D Systems (HDS), in an attempt to identify a potential cause for changes in performance, commented that the CAFE model should have placed fewer constraints on engine resizing. CARB and ICCT commented that engine resizing should have been allowed even at low levels of mass reduction. Comments from CARB, UCS, HDS, and ICCT stated that engine resizing should also have been allowed for other incremental technologies, and within their comments they conducted performance analysis of non-resized cases.

CARB claimed that requiring a minimum of 7.1% curb weight reduction before engine resizing is a constraint that "limits the optimization of the technologies being applied."[434] UCS stated that "a significant share of the benefit of a few percent reduction in mass has gone towards improved performance rather than improved fuel economy, leaving a substantial benefit of mass reduction underutilized and/or uncounted."[435] ICCT also commented that "when vehicle lightweighting is deployed at up to a 7% mass reduction, the engine is not resized even though less power would be needed for the lighter vehicle, meaning any such vehicles inherently are higher performance."[436]

UCS and HDS commented on the lack of resizing for technologies other than mass reduction, with HDS stating that "the Agencies incorrectly limited the efficacy of technologies that reduce tractive load because their modeling does not re-optimize engine performance after applying these technologies."[437] CARB also commented that the lack of resizing when a BISG or CISG system is added "results in a less than optimized system that does not take full advantage of the mild hybrid system." Similarly, ICCT noted a case in which a Dodge RAM "did not apply engine downsizing with the BISG system on that truck, so there are also significant performance benefits that should be accounted for, meaning that for constant-performance the fuel consumption reduction would be even greater."[438]

CARB further commented on the performance improvement in cases without engine resizing by stating that "94 percent of the packages modeled result in improved performance," and that for these non-resized cases that were actually adopted by a vehicle in the simulation, "fewer than 20 percent maintained baseline performance with gains of 2 percent or less in acceleration time."[439] Referring specifically to non-resized electrified vehicles, CARB also

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[434] California Air Resources Board, Attachment 2, Docket No. NHTSA-2018-0067-11873, at 178. Note, a 7.1% curb weight reduction equates to the agencies' third level of mass reduction (MR3); additional discussion of engine resizing for mass reduction can be found in Section [xxx], below.
[435] Union of Concerned Scientists, Attachment 2, Docket No. NHTSA-2018-0067- 12039, at 11.
[436] International Council on Clean Transportation, Attachment 3, Docket No. NHTSA-2018-0067-11741, at I-50.
[437] H-D Systems, Attachment 1, Docket No. NHTSA-2018-0067-12395, at 4. For reference, technologies that reduce tractive road load include mass reduction, aerodynamic drag reduction, and tire rolling resistance reduction.
[438] International Council on Clean Transportation, Attachment 3, Docket No. NHTSA-2018-0067-11741, at I-24.
[439] California Air Resources Board, Attachment 2, Docket No. NHTSA-2018-0067-11873, at 183.

stated that "44,878 of the 53,818 packages, or greater than 83 percent, result in improved performance."[440] CARB also commented that engine sharing across different vehicles within a platform, which in some cases may constrain resizing for a member of that platform, should not dictate that these engines must remain identical in all aspects, and that "this overly restrictive sharing of identical engines newly imposed in the CAFE Model is not consistent with today's industry practices and results in less optimal engine sizing and causes a systematic overestimation of technology costs to meet the existing standards."[441]

The agencies note broadly, in response to these comments, that when conducting an analysis which balances performance neutrality against the realities faced by manufacturers, such as manufacturing complexity, economies of scale, and maintaining the full range of performance criteria, it is inevitable to observe at least some minor shift in vehicle performance. For example, if a new transmission is applied to a vehicle, the greater number of gear ratios helps the engine run in its most efficient range which improves fuel economy, but also helps the engine to run in the optimal "power band" which improves performance. Thus, the technology can provide both improved fuel economy and performance. Another example is applying a small amount of mass reduction that improves both fuel economy and performance by a small amount. Resizing the engine to maintain performance in these examples would require a unique engine displacement that is only slightly different than the baseline engine. While engine resizing in these incremental cases could have some small benefit to fuel economy, the gains may not justify the costs of producing unique niche engines for each combination of technologies. If manufacturers were to produce marginally downsized engines to complement every small increment of mass reduction or technology, the resulting large number of engine variants that would need to be manufactured would cause a substantial increase in manufacturing complexity, and require significant changes to manufacturing and assembly plants and equipment.[442] The high costs would be economically infeasible.

Also, as noted in the NPRM, the 2015 NAS report stated that "[f]or small (under 5 percent [of curb weight]) changes in mass, resizing the engine may not be justified, but as the reduction in mass increases (greater than 10 percent [of curb weight]), it becomes more important for certain vehicles to resize the engine and seek secondary mass reduction opportunities."[443] In consideration of both the NAS report and comments received from manufacturers, the agencies determined it would be reasonable to allow allows engine resizing upon adoption of 7.1%, 10.7%, 14.2%, and 20% curb weight reduction, but not at 3.6% and 5.3%.[444] Resizing is also allowed upon changes in powertrain type or the inheritance of a

[440] California Air Resources Board, Attachment 2, Docket No. NHTSA-2018-0067-11873, at 187.
[441] California Air Resources Board, Attachment 2, Docket No. NHTSA-2018-0067-11873, at 185.
[442] For example, each unique engine would require unique internal components such as crankshafts, pistons, and connecting rods, as well as unique engine calibrations for each displacement. Assembly plants would need to stock and feed additional unique engines to the stations where engines are dressed and inserted into vehicles.
[443] National Research Council. 2011. Assessment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, DC – The National Academies Press. *http://nap.edu/12924*.
[444] These curb weight reductions equate to the following levels of mass reduction as defined in the analysis: MR3, MR4, MR5 and MR6, but not MR1 and MR2; additional discussion of engine resizing for mass reduction can be found in Section [xxx].

powertrain from another vehicle in the same platform. The increments of these higher levels of mass reduction, or complete powertrain changes, more appropriately match the typical engine displacement increments that are available in a manufacturer's engine portfolio.

The agencies point to the comments from manufacturers, discussed further above, which support the agencies' assertion that the CAFE model's resizing constraints are appropriate. As discussed previously, Toyota commented that this approach better considers the constraints of engineering resources and manufacturing costs and results in a more realistic number of engines and transmissions.[445] The Alliance also commented on the benefit of constraining engine resizing, stating that "the platform and engine sharing methodology in the model better replicates reality by making available to each manufacturer only a finite number of engine displacements, helping to prevent unrealistically 'over-optimized' engine sizing."[446]

Another comment from CARB stated that engine resizing "was only simulated for cases where those levels of mass reduction were applied, *in the absence of virtually all other technology or efficiency improvements.*"[447] The agencies believe that possibly due to a misinterpretation of the Autonomie simulation data, as CARB is claiming that when a vehicle adopted 7.1% or more curb weight reduction *and simultaneously adopted other technologies*, no engine resizing was allowed. In fact, for *any* case where a vehicle adopts a 7.1% or more curb weight reduction, the engine *will* be resized no matter what other technologies are already present or are added in conjunction with the mass reduction.[448] This can be observed in the Autonomie simulation databases by tracking the EngineMaxPower column (not the VehicleSized column, as the agencies suspect was done by CARB).

Commented [A158]: REVISE: The text is not responsive to the comment made by CARB. CARB is saying that engine resizing SIMULATION is performed "in the absence of virtually all other technology or efficiency improvements," they're not saying the engine resizing EFFECTIVENESS is not applied in these cases. In other words, CARB is pointing out that the engine resizing is done only for the worst applicable case.

To illustrate, for all levels of MR (including 7.1% and higher) the engine is not resized with the addition of transmission, tire, aero, EPS, IACC, LDB, SAX, EFR (i.e. except for engine architecture, 'vitually all other technology or efficiency improvements')

Suggest revising this response, considering the apparent intent of CARB's comment.

Finally, ICCT claimed that the agencies did not sufficiently report performance-related vehicle information. ICCT commented that the output files did not show data on "engine displacement, the maximum power of each engine, the maximum torque of each engine, the initial and final curb weight of each vehicle (in absolute terms), and estimated 0-60 mph acceleratiun." ICCT claimed that because this data was not found, the agencies are "showing that they have not even attempted to analyze accurately the future year fleet for their performance" and that "the agencies are intentionally burying a critical assumption, whereby their future fleet has not been appropriately downsized, and it therefore has greatly increased utility and performance characteristics."[449]

In fact, for the NPRM, and again for this final rule, the agencies did analyze vehicle performance and have made the data available to the public. An indication of the actual engine displacement change is available by noting the displacements used in Automonie simulation

[445] Toyota, Attachment 1, Docket No. NHTSA-2018-0067-12098, at 6.
[446] Alliance of Automobile Manufacturers, Attachment "Full Comment Set", Docket No. NHTSA-2018-0067-12073, at 140.
[447] California Air Resources Board, Attachment 2, Docket No. NHTSA-2018-0067-11873, at 178.
[448] For example, if a vehicle possesses MR2, AERO1, and ROLL1 and subsequently adopts MR3, AERO1, *ROLL2*, the engine *will* be resized and will adopt the lower engine power level associated with MR3. As a counter example, if a vehicle possesses MR3, ROLL1, and AERO1 and subsequently adopts MR3, ROLL1, *AERO2*, the engine *will not* be resized and it will retain the power level associated with MR3.
[449] International Council on Clean Transportation, Attachment 3, Docket No. NHTSA-2018-0067-11741, at I-74.

database for each of the technology states. The displacements reported in Autonomie are used by the full-vehicle-simulation within the Autonomie model, and while they do not directly represent each specific vehicle's actual engine sizes, they do fully reflect the relative change in engine size that is applied to each vehicle. It is the relative change in engine size that is relevant for the analysis. Similarly, the vehicle power and torque used by the full vehicle simulations are reported in the Autonomie simulation databases; their values and relative change across an engine resizing event can be observed. Initial and final curb weights for the analysis fleet are reported in Vehicles Report output file column titled "CW Initial" and "CW", respectively. The time required for 0-60mph acceleration is reported in the Autonomie simulation database files. A detailed description of the engine resizing methodology is available in the ANL Model Documentation, which explains how vehicle characteristics are used to calculate powertrain size.[450] These data and information that are available in the Autonomie and CAFE model documentation provide the information needed to analyze performance, and in fact, this is evidenced by the statements of numerous commenters discussed in this section. The agencies have conducted their own performance analysis, which is discussed further below, using the same data documentation mentioned here.

Updates to the CAFE model have minimized performance shift over the simulated model years, and have eliminated performance differences between simulated standards.

The Autonomie simulation updates, discussed previously, were included in the final rule analysis, and have resulted in average performance that is similar across the regulatory alternatives. Because the regulatory analysis compares differences in impacts among the alternatives, the agencies believe that having consistent performance across the alternatives is an important aspect of performance neutrality. If the vehicle fleet had performance gains which varied significantly depending on the alternative, performance differences would impact the comparability of the simulations. Using the NPRM CAFE model data, the agencies analyzed the sales-weighted average 0-60 performance of the entire simulated vehicle fleet for MYs 2016 and 2020, and identified that the Augural standards had 4.7% better 0-60 mph acceleration time compared to the NPRM preferred alternative, which had no changes in standards in MYs 2021-2026.[451] This assessment confirmed the observations of the various commenters. With the refinements that were incorporated for the final rule, similar analysis showed that the Augural

[450] [insert reference to the FRM ANLModel Documentation document].

[451] The agencies' analysis matched all MY 2016 and MY 2029 vehicles in the NPRM Vehicles Report output file, under both the Augural standards and preferred alternative, with the appropriate 0-60 mph acceleration time from the NPRM Autonomie simulation databases. This was done by examining each vehicle's assigned technologies, finding the Autonomie simulation with the corresponding set of technologies, and extracting that simulation's 0-60 mph acceleration time. This process effectively assigned a 0-60 time to every vehicle in the fleet for four scenarios: 1) MY 2016 under augural standards, 2) MY 2016 under the preferred alternative, 3) MY 2029 under augural standards, and 4) MY 2029 under the preferred alternative. For each scenario, an overall fleet-wide weighted average 0-60 time was calculated, using each vehicle's MY2016 sales volumes as the weight. For more information, see the FRIA at [xxx].

standards had a negligible 0.3% difference in 0-60 mph acceleration time compared to the NPRM preferred alternative.[452]

The updates applied to the final rule Autonomie simulations also resulted in further minimizing the performance change across model years. As the agencies' attempted to minimize this performance shift occurring "over time," it was also acknowledged that a small increase would be expected and would be reasonable. This increase is attributed to the analysis recognizing the practical constraints on the number of unique engine displacements manufacturers can implement, and therefore not resizing powertrains for every individual technology and every combination of technologies when the performance impacts are small. Perfectly equal performance with 0% change would not be achievable while accounting for these real world resizing constraints. The performance analysis in the 2011 NAS report shared a similar view on performance changes, stating that "truly equal performance involves nearly equal values… within 5 percent."[453] In response to comments, using NPRM CAFE model data, the agencies analyzed the sales-weighted average 0-60 performance of the entire simulated vehicle fleet, and identified that the performance increase from MYs 2016 and 2029 was 7.5% under Augural Standards and 3.1% under the NPRM preferred alternative standards. The agencies conducted a similar analysis using final rule data and found the performance increase over time from MYs 2017 to 2029 was 3.7% for Augural Standards and 4.0% for the NPRM preferred alternative standards. The agencies determined this change in performance is reasonable and note it is within the 5 percent bound in discussed by NAS in its 2011 report.

Commented [A159]: REVISE: The numbers presented here do not align with the information provided by NHTSA to EPA in 2019, in which the Augural Standards had approx. 1% higher performance than the NPRM preferred alternative. Suggest 1) confirming that these numbers are correct, and represent the average of the percent changes by vehicle, rather than the percent change in the average (which would also reflect changes in sales mix), and 2) citing the docket number of the underlying Autonomie performance results here.

This assessment shows that for the final rule analysis, performance is neutral across regulatory alternatives and across the simulated model years allowing for fair, direct comparison among the alternatives.

(7) How We Simulated Vehicle Models on Test Cycles

After vehicle models are built for every combination of technologies and vehicle classes represented in the analysis, Autonomie simulates their performance on test cycles to calculate the effectiveness improvement of the fuel-economy-improving technologies that have been added to the vehicle. Discussed earlier, we minimize the impact of potential variation in determining effectiveness by using a series of tests and procedures specified by federal law and regulations under controlled conditions.

[452] This updated analysis used the FRM Vehicles Report output file and the FRM Autonomie simulation databases. The final rule analysis introduced an updated MY 2017 fleet as a starting point, replacing the NPRM 2016MY fleet. For more information, see the FRIA at Chapter [xxx].
[453] National Research Council. 2011. Assessment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, DC – The National Academies Press, at 62. *http://nap.edu/12924.*

Autonomie simulates vehicles in a very similar process as the test procedures and energy consumption calculations that manufacturers must use for CAFE and CO_2 compliance.[454, 455, 456] ANL simulated each vehicle model on several test procedures to evaluate effectiveness. For vehicles with conventional powertrains and micro hybrids, Autonomie simulates the vehicles on EPA 2-cycle test procedures and guidelines.[457] For mild and full hybrid electric vehicles and FCVs, Autonomie simulates the vehicles using the same EPA 2-cycle test procedure and guidelines, and the drive cycles are repeated until the initial and final state of charge are within a SAE J1711 tolerance. For PHEVs, Autonomie simulates vehicles in similar procedures and guidelines as SAE J1711.[458] For BEVs and FCVs, Autonomie simulates vehicles in similar procedures and guidelines as SAE J1634.[459]

b) Selection of One Full-vehicle Modeling and Simulation Tool

The NPRM described tools that the agencies previously used to estimate technology effectiveness. For the analysis supporting the 2012 final rule for MYs 2017 and beyond, the agencies used technology effectiveness estimates from EPA's lumped parameter model (LPM). The LPM was calibrated using data from vehicle simulation work performed by Ricardo Engineering.[460] The agencies also used full vehicle simulation modeling data from Autonomie vehicle simulations performed by ANL for mild hybrid and advanced transmission effectiveness estimates.[461, 462]

For the 2016 Draft TAR analysis, EPA and NHTSA used two different full system simulation programs for complementary but separate analyses. NHTSA used ANL's Autonomie tool, described in detail above, with engine map inputs developed by IAV using GT-Power in 2014, and updated in 2016.[463, 464, 465] ANL, in coordination with NHTSA, developed a

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[454] EPA. "How Vehicles are Tested." https://www.fueleconomy.gov/feg/how_tested.shtml. Last accessed Nov 14, 2019.
[455] ANL model documentation for final rule Chapter 6. Test Procedures and Energy Consumption Calculations.
[456] EPA Guidance Letter. "EPA Test Procedures for Electric Vehicles and Plug-in Hybrids." Nov. 14, 2017. https://www.fueleconomy.gov/feg/pdfs/EPA%20test%20procedure%20for%20EVs-PHEVs-11-14-2017.pdf. Last accessed Nov. 7, 2019.
[457] 40 CFR Part 600.
[458] PHEV testing is broken into several phased based on SAE J1711. Charge-Sustaining on the City cycle, Charge-Sustaining on the HWFET cycle, Charge-Depleting on the City and HWTET cycles.
[459] SAE J1634. "Battery Electric Vehicle Energy Consumption and Range Test Procedure." July 12, 2017.
[460] Response to Peer Review of: Ricardo Computer Simulation of Light-Duty Vehicle Technologies for Greenhouse Gas Emission Reduction in the 2020-2025 Timeframe, EPA-420-R-11-021 (December 2011), available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100D5BX.PDF?Dockey=P100D5BX.PDF.
[461] Joint TSD: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Emission Standards and Corporate Average Fuel Economy Standards. August 2012. EPA-420-R-12-901.3.3.1.3 Argonne National Laboratory Simulation Study p. 3--69
[462] Moawad, A. and Rousseau, A., "Impact of Electric Drive Vehicle Technologies on Fuel Efficiency," Energy Systems Division, Argonne National Laboratory, ANL/ESD-12-7, August 2012.
[463] GT-Power Engine Simulation Software. https://www.gtisoft.com/gt-suite-applications/propulsion-systems/gt-power-engine-simulation-software/. Last accessed Oct. 10, 2019.
[464] 2016 Draft TAR Engine Maps by IAV Automotive Engineering using GT-Power. https://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/IAV_EngineMaps_Details.xlsx. Lass accessed Oct. 10, 2019.
[465] NHTSA-2018-0067-0003. ANL - Summary of Main Component Performance Assumptions NPRM.

methodology for large scale simulation using Autonomie and distributed computing, thus overcoming one of the challenges to full vehicle simulation that the NAS committee outlined in its 2015 report and implementing a recommendation that the agencies use full-vehicle simulation to improve the analysis method of estimating technology effectiveness.[466] EPA used a limited number of full-vehicle simulations performed using its ALPHA model, an EPA-developed full-vehicle simulation model,[467] to calibrate the LPM, used to estimate technology effectiveness. EPA also used the same modeling approach for its Proposed Determination analysis.[468]

~~As discussed in more detail below, although Autonomie and ALPHA are both models that perform full-vehicle simulation, the ALPHA model does not currently have Autonomie's large-scale simulation capabilities, and is unable to perform a full parametric study of effectiveness estimates with every individual vehicle technology being investigated.~~ Again, the use of large-scale modeling and simulation minimizes errors by directly evaluating effectiveness of each technology and combination of technologies. ~~This ALPHA limitation necessitates the use of a tool that is trained using limited ALPHA data to provide approximate effectiveness values for the wide range of technology combinations. EPA highlighted some of the issues surrounding the use of ALPHA and the LPM instead of large-scale modeling and simulation in the 2018 SAE Government Meeting when it presented a replacement tool for the LPM, a Response Surface Model (RSM) used to synthesize a large set of simulation outputs computationally to derive response surface equations (RSEs) that can be used in place of running the ALPHA model.[469] EPA has continued development of its RSEs to supplement the ALPHA modeling framework.[470]~~

Commented [A160]: DELETE: It is factually incorrect that ALPHA does not have large scale simulation capabilities. Parallel computing, batch input and output files, and efficient computational approaches have been utilized to generate results for hundreds of thousands vehicle simulations.

Commented [A161]: DELETE: This is not an accurate characterization of EPA's presentation at the 2018 SAE G-I meeing which described the improved process efficiency and transparency of using RSE's instead of LPM's. Contrary to what is described here, neither LPM's nor RSE's are incompatible with large scale modeling. To illustrate, RSE's could be adopted to improve the fidelity and resolution of the Autonomie large scale simulation results by including each vehicle's specific power-to-weight, curb weight, and road load attributes, as is the case with EPA's LPM and RSE processes.

Rather than contrasting LPM/RSE vs. large scale simulation, a more appropriate comparison would be between the LPM/RSE continuous representation of continuous variables vs. discrete representation of continuous variables using lookup tables. In any case, such a discussion is not really necessary here to present the FRM analysis, so EPA suggests deleting this text rather than revising it.

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[466] *See* National Research Council. 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, DC: The National Academies Press [hereinafter "2015 NAS Report"] at p. 263, available at https://www.nap.edu/catalog/21744/cost-effectiveness-and-deployment-of-fuel-economy-technologies-for-light-duty-vehicles (last accessed June 21, 2018). *See also* A. Moawad, A. Rousseau, P. Balaprakash, S. Wild, "Novel Large Scale Simulation Process to Support DOT's CAFE Modeling System," International Journal of Automotive Technology (IJAT), Paper No. 220150349, Nov 2015; Pagerit, S., Sharper, P., Rousseau, A., Sun, Q. Kropinski,, M. Clark, N., Torossian, J., Hellestrand, G., " Rapid Partitioning, Automatic Assembly and Multicore Simulation of Distributed Vehicle Systems." ANL, General Motors, EST Embedded Systems Technology. 2015. https://www.autonomie.net/docs/5%20-%20Presentations/VPPC2015_ppt.pdf. Last accessed Dec. 9, 2019.

[467] *See* Lee, B., S. Lee, J. Cherry, A. Neam, J. Sanchez, and E. Nam. 2013. Development of Advanced Light-Duty Powertrain and Hybrid Analysis Tool. SAE Technical Paper 2013-01-0808. doi: 10.4271/2013-01-0808.

[468] Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, EPA-420-R-16-020 (November 2016), available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100Q3DO.pdf; Final Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, EPA-420-R-17-001 (January 2017), available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100QQ91.pdf.

~~[469] Olechiw, M. EPA. "End-to-End Use of Alpha Vehicle Simulation in EPA's CO2 Standards Assessments: From Baseline to Future Fleets." SAE G-I Meeting. January 25, 2018. https://www.epa.gov/sites/production/files/2018-10/documents/2018-sae-gm1-indst-olechiw-2018-01.pdf. Last accessed Nov. 14, 2019.~~

~~[470] See Peer Review of EPA's Response Surface Equation Report, EPA-420-R-18-006 (May 2018), available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100VK3Z.pdf; Moskalik, A., Bolon, K., Newman, K., and Cherry, I. "Representing CO2 Reduction Technologies in the Future Fleet with Full Vehicle Simulation." SAE Technical Paper 2018-01-1273, 2018, doi:10.4271/2018-01-1273.~~

~~In the subsequent August 2017 Request for Comment on Reconsideration of the Final Determination of the Mid-Term Evaluation of Greenhouse Gas Emissions Standards for MY 2022-2025 Light Duty Vehicles, the agencies requested comments on whether EPA should use alternative methodologies and modeling, including the Autonomie full vehicle simulation tool and DOT's CAFE model, for the analysis that would accompany its revised Final Determination.[421] As discussed in the NPRM, some auto industry stakeholders questioned the efficacy of the combined outputs and assumptions of the LPM and ALPHA,[422] especially as the tools were used to evaluate increasingly heterogeneous combinations of technologies in the vehicle fleet.[423]~~

~~More specifically, the Auto Alliance noted that their previous comments to the midterm evaluation, in addition to comments from individual manufacturers, highlighted multiple concerns with EPA's ALPHA model that were unresolved, but addressed in Autonomie.[424] First, the Alliance expressed concern over ALPHA modeling errors related to road load reductions, stating that an error derived from how mass and coast-down coefficients were updated when mass, tire and aero improvements were made resulted in benefits overstated by 3% to 11% for all vehicle types. Next, the Alliance repeated its concern that EPA should consider top gear gradeability as one of its performance metrics to maintain functionality, noting that EPA had acknowledged the industry's comments in the Proposed Determination, "but generally dismissed the auto industry concerns." Additional analysis by EPA in its Response to Comments document did not allay the Alliance's concerns,[425] as the Alliance concluded that "[c]onsistent with the National Academy of Sciences recommendation from 2011, EPA should monitor gradeability to ensure minimum performance."~~

~~Furthermore, the Alliance stated that ALPHA vehicle technology walks provided in response to manufacturer comments on the Proposed Determination did not correctly predict cumulative effectiveness when compared to technologies in real world applications. The Alliance stated that many of the individual technologies and assumptions used by ALPHA overestimated technology effectiveness and were derived from questionable sources. As an example, the Alliance referenced an engine map used by EPA to represent the Honda L15B7 engine, where the engine map data was collected by "(1) taking a picture of an SAE document containing an image of the engine map, and then (2) 'digitizing' the image by 'tracing image contours'" (citing EPA's ALPHA documentation). The Alliance could not definitively state whether the "digitization" process, lack of detail in the source image, or another factor were the~~

~~[421] 82 FR 39551 (Aug. 21, 2017).~~

~~[422] 82 FR 43022 (Auto Alliance 2016-0018-0082, p. 19). EPA provided the following comments: "EPA believes EPA is overestimating the benefits of technology. As the LPM is calibrated to these projections, so too is the LPM an opinionic." EPA also shared the chart, 'LPM vs. Actual 6-vs-8 Speed Transmissions.'"~~

~~[423] 82 FR 43022 (referencing Automotive News, "CAFE mulls get-tougher or industry innovate," Kolinski, March 26, 2018).~~

~~[424] EPA-HQ-OAR-2015-0827-9194, at p. 30-11.~~

~~[425] The Alliance noted that in higher gear count transmissions, like 8-speed automatics, modeled by ALPHA with an expanded ratio spread to achieve fuel economy, are concerning for gradeability. "Additionally, aggressive engine downsizing along with expanded ratio spread transmissions, in real world gradeability may cause further deterioration as modeled in ALPHA, which leads to inflated effectiveness values for powertrains that would not meet customer demands.~~

Commented [A162]: **DELETE:** The following paragraphs do not accurately represent the LPM/ALPHA models, and include multiple factual inaccuracies. Rather than significantly revising, suggest deleting, as this discussion is not necessary to describe the technical analysis supporting this rule.

Commented [A163]: **DELETE:** The example given in the footnote has already been responded to by EPA previously. FCA was pointing out that their eight-speed transmission with a certain package of technology was not as effective as a modeled transmission including a more extensive technology package. That's to be expected, and actually supports LPM projections.

Commented [A164]: **DELETE:** Not accurate.

Commented [A165]: **DELETE:** This discussion of EPA's use of the Honda engine map for the Proposed Determination is not germane to the decision of whether to use the Autonomie model for the analysis and should be deleted.

As a side note, EPA has benchmarked this actual engine and compared the results to the initial image-based estimates. The final CO2 estimates using the two maps differed by almost exactly 1%. [Ref SAE paper 2018-01-0319] The minor differences that did exist between the initial and more recent maps were found to be influenced by differences in the subsequent iterations of the actual engines, and not simply the result of the processes used to create the maps.

~~reasons that some regions of overestimated efficiency were observed in the engine map, but concluded that "the use of this map should be discontinued within ALPHA," and "any analysis conducted with it is highly questionable." Based on these concerns and others, the Alliance recommended that Autonomie be used to inform the downstream cost optimization models (i.e., the CAFE model and or OMEGA).~~

Global Automakers argued that NHTSA's CAFE model, which incorporates data from Autonomie simulations, provided a more transparent and discrete step through each of the modeling scenarios.[476] ~~Global pointed out that the LPM is "of particular concern due to its simplified technology projection processes," and it "propagates fundamentally flawed content into the ALPHA and OMEGA models and therefore cannot accurately assess the efficacy of fuel economy technologies."~~ Global did note that EPA "plans to abandon its reliance on LPM in favor of another modeling approach," referring to the RSE, but stated that "EPA must provide stakeholders with adequate time to evaluate the updated modeling approach, ensure it is analytically robust, and provide meaningful feedback." Global Automakers concluded that EPA's engine mapping and tear-down analyses have played an important role in generating publicly-available information, and stated that the data should be integrated into the Autonomie model.

~~On the other hand, other stakeholders commented that EPA's ALPHA modeling should continue to be used, for procedural reasons like, "[i]t would appear arbitrary for EPA now, after five years of modeling based on ALPHA, to declare it can no longer use its internally developed modeling tools and must rely solely on the Autonomie model," and "[t]he ALPHA model is inextricably built into the regulatory and technical process. It will require years of new analysis to replace the many ALPHA and OMEGA modeling inputs and outputs that permeate the entire rulemaking process, should EPA suddenly decide to change its models."[477] Commenters also cited technical reasons to use ALPHA, like EPA's progress benchmarking and validating the ALPHA model to over fifteen various MY 2013-2015 vehicles,[478] and that technologies like the "Atkinson 2" engine technology were not considered in NHTSA's compliance modeling.[479] Commenters also cited that ALPHA was created to be publicly available, open-sourced, and peer reviewed, "to allow for transparency to both automakers and public stakeholders, without hidden and proprietary aspects that are present in commercial modeling products."[480]~~

The agencies described in the NPRM that after having reviewed comments about whether EPA should use alternative methodologies and modeling, and after having considered the matter fully, the agencies determined it was reasonable and appropriate to use Autonomie for full-vehicle simulation.[481] The agencies stated that nothing in Section 202(a) of the Clean Air Act (CAA) mandated that EPA use any specific model or set of models for analysis of potential CO_2 standards for light duty vehicles. The agencies also distinguished the models and the inputs used

Commented [A166]: DELETE: Overall, the comments in these preceeding paragraphs, particularly the last about the engine map "...conflated aspects of the [ALPHA] models with technology inputs and input assumptions," an error of logic pointed out by NHTSA earlier in this section (quote from above). Better, perhops, to "distinguish the models and the inputs used to populate them" (from below)

Commented [A167]: DELETE: It is a dramatic overstatement to claim that "ALPHA and OMEGA cannot accurately assess the efficacy of fuel economy technologies" due to the LPM model. EPA has already responded thoroughly to critiques from this commenter, including claims that the LPM was "fundamentally flawed" and EPA has identified major issues in the analalysis the commenter was using to reach this conclusion. In general, there is no fundamental reason why the LPM, when supplied with appropriate inputs from the ALPHA model or other full vehicle simulation, would not be able to generate appropriate effectiveness estimates for use in OMEGA. In any case, a full discussion of the LPM model is not necessary to repepeat here since it was not used for this FRM.

Commented [A168]: DELETE: This comment regarding the use of inputs developed by EPA is not relevant to the discussion of whether it is appropriate to use the Autonomie model for this analysis.

[476] EPA-HQ-OAR-2015-0827-9728, at 14.
~~[477] EPA-HQ-OAR-2015-0827-9728, at 39-40.~~
~~[478] EPA-HQ-OAR-2015-0827-9728, at 40.~~
~~[479] EPA-HQ-OAR-2015-0827-9197, at 28.~~
~~[480] EPA-HQ-OAR-2015-0827-9728, at 28.~~
[481] 83 FR 43001.

to populate them; specifically, comments presented as criticisms of the models, such as "Atkinson 2" engine technology not considered in the compliance modeling, actually concerned model inputs.[482]

With regards to modeling technology effectiveness, the agencies concluded that, although the CAFE model requires no specific approach to developing effectiveness inputs, the National Academy of Sciences recommended, and stakeholders have commented, that full-vehicle simulation provides the best balance between realism and practicality. As stated above, Argonne has spent several years developing, applying, and expanding means to use distributed computing to exercise its Autonomie full-vehicle simulation tool at the scale necessary for realistic analysis of technologies that could be used to comply with CAFE and CO_2 standards, and this scalability and related flexibility (in terms of expanding the set of technologies to be simulated) makes Autonomie well-suited for developing inputs to the CAFE model.

~~In response to the NPRM, the Auto Alliance commented that NHTSA's modeling and analysis tools are superior to EPA's, noting that NHTSA's tools have had a significant lead in their development.[483] The Alliance pointed out that Autonomie was developed from the beginning to address the complex task of combining two power sources in a hybrid powertrain, while the Alliance asserted that EPA's ALPHA model had not been validated or used to simulate hybrid powertrains. While both models are physics-based forward looking vehicle simulators, the Alliance commented that Autonomie is fully documented with available training, while ALPHA "has not been documented with any instructions making it difficult for users outside of EPA to run and interpret the model." The Alliance also mentioned specific improvements in the Autonomie simulations since the Draft TAR, including expanded performance classes to better consider vehicle performance characteristics, the inclusion of gradeability as a performance metric, as recommended by the NAS, the inclusion of new fuel economy technologies, and the removal of unproven technologies.~~

The Alliance, Global Automakers, and other automakers writing separately all stated that the agencies should use one simulation and modeling tool for analysis.[484, 485] The Alliance stated that since both the Autonomie and ALPHA modeling systems answer essentially the same questions, using both systems leads to inconsistencies and conflicts, and is inefficient and counterproductive.

The agencies agree with the Alliance that the fully developed and validated Autonomie model fulfills our analytical needs for full-vehicle modeling and simulation. ~~We also agree that it is counterintuitive to have two separate models conducting the same work.~~

Commented [A169]: DELETE: While not necessary to support the use of Autonomie for this FRM, the comments as summarized here would require a detailed and accurate reponse, since they do not accurately characterize the ALPHA model. For example, contrary to what is written here, ALPHA has been used to model multiple performance classes (really a question of inputs), multiple performance criteria including gradability, and new fuel economy technologies (again, a question of inputs.) Furthermore, ALPHA source code is open and available for free, in contrast with Autonomie which is a paid-license software with source code that is not available to the end user.

[482] 83 FR 43002.

~~[483] NHTSA-2018-0067-12073~~

[484] NHTSA-2018-0067-12073; NHTSA-2018-0067-12032. Comments of the Association of Global Automakers, Inc. on the Safer Affordable Fuel-Efficient Vehicles Rule Docket ID Numbers: NHTSA-2018-0067 and EPA-HQ-OAR-2018-0283 October 26, 2018.

[485] NHTSA-2018-0067-11943. FCA Comments on The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks Notice of Proposed Rulemaking.

Some commenters stated that broadly, EPA was required to conduct its own technical analysis and rely on its own models to do so.[486] Those comments are addressed in Section [IV].

~~Regarding the merits of EPA's models, ICCT commented that "[b]ased on the ICCT's global analysis of vehicle regulations, the EPA's physics-based ALPHA modeling offers the most sophisticated and thorough modeling of the applicable technologies that has ever been conducted." ICCT listed several reasons for this, including that the EPA modeling is based on systematic modeling of technologies and their synergies; it was built and improved upon by extensive modeling by and with Ricardo (an engineering consulting firm); it incorporated National Academies input at multiple stages; it has included many peer reviews at many stages of the modeling and the associated technical reports published by engineers in many technical journal articles and conference proceedings; and EPA's Draft TAR analysis, which used ALPHA, used state-of-the-art engine maps based on benchmarked high-efficiency engines. ICCT concluded that "[d]espite these rigorous advances in vehicle simulation modeling, it appears that the agencies have inexplicably abandoned this approach, expressly disregarding the EPA benchmarked engines, ALPHA modeling, and all its enhancements since the last rulemaking."~~

~~The hallmarks ICCT lists regarding the ALPHA modeling are equally applicable to Autonomie.[487] Autonomie is also based on systematic modeling of technologies and their synergies when combined as packages. The U.S. Department of Energy created Autonomie, and over the past two decades, helped to develop and mature the processes and inputs used to represent real-world vehicles using continuous feedback from the tool's worldwide user base of vehicle manufacturers, suppliers, government agencies, and other organizations. Moreover, using Autonomie brings the agencies closer to the NAS Committee's stated goal of "full system simulation modeling for every important technology pathway and for every vehicle class."[488] While the NAS Committee originally thought that full vehicle simulation modeling would not be feasible for the thousands of vehicles in the analysis fleets because the technologies present on the vehicles might differ from the configurations used in the simulation modeling,[489] ANL has developed a process to simulate explicitly every important technology pathway for every vehicle class. Moreover, although separate from the Autonomie model itself, the Autonomie modeling for this rulemaking incorporated other NAS committee recommendations regarding full vehicle simulation inputs and input assumptions, including using engine-model generated maps derived from a validated baseline map in which all parameters except the new technology of interest are held constant.[490]~~

~~As discussed further below and in Section [Engine Maps], this is one of the main reasons why the agencies decided not to use EPA engine benchmarking maps as inputs to Autonomie, instead referencing EPA's engine maps to corroborate the Autonomie effectiveness results. While EPA's benchmarked engine maps incorporate multiple technologies, for example~~

Commented [A170]: DELETE: The discussion here about the choice of inputs is not relevent to the supporting discussion of of which simulation model should be used for this rulemaking.

Commented [A171]: DELETE: This is equally true of ALPHA which similarly has large scale simulation capability.

Commented [A172]: DELETE: This is not a factually accurate summary of the rationale for the use of IAV engine maps. Even setting aside a discussion of the relative merits of EPA or IAV engine maps, the EPA Administrator's decision to rely on the NHTSA analysis was not made on an individual assumption-by-assumption basis, but rather the broader decision to use the NHTSA/VOLPE/ANL suite of models and inputs.

[486] NHTSA-2018-0067-12000; NHTSA-2018-0067-12039.

[487] ~~See Theo LeSage, *Two-Speed Lockup Trans* (1981), at 1-32.~~

[488] ~~2015 NAS Report at 358.~~

[489] ~~2015 NAS Report at 359.~~

[490] ~~NAS Recommendation 2-1.~~

~~including improvements in engine friction and reduction in accessory parasitic loads. comparisons showed engine maps developed by IAV are in line with EPA's engine benchmarking data. This is further discussed in Section [Engines] below.~~

~~In addition, both ALPHA and~~ Autonomie ~~have~~ has been used to support analyses that have been published in technical journal articles and conference proceedings~~, but those analyses differ fundamentally because of the nature of the tools. ALPHA was developed as a tool to be used by EPA's in-house experts.[400] As EPA stated in the ALPHA model peer review,[401] "ALPHA is not intended to be a commercial product or supported for wide external usage as a development tool."[402] Accordingly, EPA experts have published several peer-reviewed journal articles using ALPHA and have presented the results of those papers at conference proceedings.[403]~~

~~The agencies believe it also is important to take the actual substantive content of the ALPHA peer review into account.[404] One reviewer raised significant questions over the availability of ALPHA documentation, stating "[t]here is an overall lack of detail on key technical features that are new in the model," and "[w]e were not able to find any information on how the model handles component weight changes." Reviewers also raised questions related to model readiness, stating "[a]ccording to the documentation review, ALPHA's stop/start modeling appears to be very simplistic." Moreover, when running ALPHA simulations, the reviewer noted the results "strongly suggest that the model has errors in the underlying equations or coding with respect to all of the load reductions." Also, one reviewer said the following of ALPHA: "A specific simulation runtime is significantly high, more than 10 mins. without providing any indication to the user progress made so far. A fairly more complicated model such as Autonomie available even with enhanced capabilities is significantly faster today."~~

The peer reviewer's assessment of Autonomie as a more complicated model with enhanced capabilities is not surprising, given Autonomie's history of development. Autonomie is a commercial tool with more than 275 worldwide organizational users, including vehicle manufacturers, suppliers, government agencies, and nonprofit organizations having licensed and used Autonomie. Both Autonomie's creators and user base unaffiliated with ANL have published over 100 papers, including peer-reviewed papers in journals, related to Autonomie

Commented [A173]: DELETE: In an abosolute sense, this statement is not factually correct. There are significant differences, both in baseline engine technologies and those with more advanced technologies between the IAV and EPA engine maps. Even when the incremental effectiveness between two technologies may be similar, the maps themselves are quite different.

Commented [A174]: DELETE: EPA does not agree with the commenters characterization of the ALPHA model, but in any case a detailed rebuttal is not required here in order to support the use of Autonomie for this rule.

~~[400] ALPHA Peer Review, at 1-1.~~

~~[401] ICCT's comments intimate that ALPHA has been peer reviewed at many stages of the modeling, although EPA has published several peer-reviewed technical papers, the ALPHA model itself has been subject to one peer-review. See Peer Review of ALPHA Full Vehicle Simulation Model, available at https://nepis.epa.gov/Exe/ZyPDF.cgi/P100PL4L.pdf.~~

~~[402] ALPHA Peer Review, at 1-2.~~

~~[403] See, e.g., Dekraker, P., Kargul, J., Moskalik, A., Newman, K., et al., "Fleet-Level Modeling of Real World Factors Influencing Greenhouse Gas Emissions Simulation in ALPHA," SAE Int. J. Fuels Lubr. 10(1):2017, doi:10.4271/2017-01-0900.~~

~~[404] EPA, "Peer Review of ALPHA Full Vehicle Simulation Model," EPA-420-R-16-013, October 2016, https://nepis.epa.gov/Exe/ZyPDF.cgi/P100PL4L.pdf. Last accessed Nov. 15, 2016.~~

validation and other studies.[496,497] One could even argue that the tool has been continuously peer reviewed by these thousands of experts over the past two decades.

In fact, in responding to a peer review comment on the ALPHA model's underlying equations and coding with respect to road load reductions, EPA noted that Autonomie had been used as a reference system simulation tool to validate ALPHA model results.[498]

Outside of formal peer-reviewed studies, Autonomie has been used by organizations like ICCT to support policy documents, position briefs, and white papers assessing the potential of future efficiency technologies to meet potential regulatory requirements,[499] just as the agencies did in this rulemaking.

Similarly to ICCT, UCS stated that in contrast to Autonomie, ALPHA had been thoroughly peer-reviewed and is constantly being updated to reflect the latest technology developments based on work performed by the National Vehicle and Fuel Emissions Laboratory.[500] UCS also stated that because EPA has direct control over the model and its interface to OMEGA, EPA can better ensure that the inputs into OMEGA reflect the most up-to-date data, unlike the Autonomie work, which effectively has to be "locked in" before it can be deployed in the CAFE model. UCS also stated that ALPHA is based on the GEM model (used to simulate compliance with heavy-duty vehicle regulations) which was been updated with feedback from heavy-duty vehicle manufacturers and suppliers, and in fact, "NHTSA has such confidence in the GEM model that they accept its simulation-based results as compliance with the heavy-duty fuel economy regulations."

Again, the agencies believe that it is important to note that Autonomie not only meets, but also exceeds, UCS' listed metrics. Autonomie's models, submodels, and controls are constantly being updated to reflect the latest technology developments based on work performed by Argonne National Laboratory's Advanced Mobility Technology Laboratory (AMTL)

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[496] At least 15 peer-reviewed papers authored by ANL experts have been referenced throughout this Section, and others can be found at SAE International's website, https://www.sae.org/, using the search bar for "Autonomie."
[497] *See, e.g.*, Haupt, T., Henley, G., Card, A., Mazzola, M. et al., "Near Automatic Translation of Autonomie-Based Power Train Architectures for Multi-Physics Simulations Using High Performance Computing," SAE Int. J. Commer. Veh. 10(2):483-488, 2017, https://doi.org/10.4271/2017-01-0267; Samadani, E., Lo, J., Fowler, M., Fraser, R. et al., "Impact of Temperature on the A123 Li-Ion Battery Performance and Hybrid Electric Vehicle Range," SAE Technical Paper 2013-01-1521, 2013, https://doi.org/10.4271/2013-01-1521.
[498] Peer Review of ALPHA Full Vehicle Simulation Model, at 4-14 and 4-15, available at https://nepis.epa.gov/Exe/ZyPdf.cgi?Dockey=P100PUKT.pdf.
[499] *See, e.g.*, Oscar Delgado and Nic Lutsey, Advanced Tractor-Trailer Efficiency Technology Potential in the 2020-2030 Timeframe (April 2015), available at https://theicct.org/sites/default/files/publications/ICCT_ATTEST_20150420.pdf; Ben Sharpe, Cost-Effectiveness of Engine Technologies for a Potential Heavy-Duty Vehicle Fuel Efficiency Regulation in India (June 2015), *available at* https://theicct.org/sites/default/files/publications/ICCT_position-brief_HDVenginetech-India_jun2015.pdf; Ben Sharpe and Oscar Delgado, Engines and tires as technology areas for efficiency improvements for trucks and buses in India (working paper published March 2016), available at https://theicct.org/sites/default/files/publications/ICCT_HDV-engines-tires_India_20160314.pdf.
[500] NHTSA-2018-0067-12039 (UCS).

(formerly Advanced Powertrain Research Facility, or ARPF).[501,502] The Autonomie validation has included nine validation studies with accompanying reports for software, six validation studies and reports for powertrains, nine validation studies and reports for advanced components, ten validation studies and reports for advanced controls, and overall model validation using test data from over 50 vehicles.[503]

In fact, using Autonomie, which has validated data based on test data from over 50 vehicles, alleviates other stakeholder concerns about the level of model validation in past analyses. ~~For example, concerns about whether ALPHA's effectiveness values were properly validated were identified in the Global Automaker's comments in response to the reconsideration of the final determination, where Global stated that "[a]lthough EPA claims that the LPM was calibrated based on thorough testing and modeling with the ALPHA model, the materials provided with the Proposed and Final Determination only cover 18% of the projected vehicle fleet with regards to specific combinations of powertrain technology presented by EPA in the MY 2025 OMEGA pathway. It is unclear how EPA calibrated the LPM for the remaining 82% of the projected vehicles. EPA's failure to publicly share the data for such a large percentage of vehicles raises questions about the quality of data."[504] While simple modeled parameters like single dimensional linear systems, like engine dynamometer torque measurements can be validated through other models,[505] full vehicle systems are complex multi-dimensional non-linear systems that need to be developed with multiple data sets, and validated with other fully independent data sets. Autonomie's models and sub-models have undergone extensive validation that has proven the models' agreement with empirical data and the principles of physics.~~

Commented [A175]: DELETE: This section contains both factually incorrect statements, and mistakenly implies that EPA's effectiveness modeling processes are not in agreement with the principles of physics.

Specifically, the claim about 18% coverage of technologies (if accepted without rebuttal for the ALPHA modeling) is potentially problematic for the Autonomie runs since they contain a number of technologies which are represented as fixed effectiveness values (which even the LPM does not do.)

In other words, the inclusion of this comment for the purpose of denigrating the ALPHA/LPM models is an inaccurate, selective parsing of the comments. It's not necessary for supporting the use of Autonomie, and should be deleted.

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[501] *See* NPRM PRIA. The agencies cited a succinctly-summarized presentation of Autonomie vehicle validation procedures based on AMTL test data in the NPRM ANL modeling documentation and PRIA docket for stakeholders to review at [PRIA and ANL documentation Docket IDs].

[502] Jeong, J., Kim, N., Stutenberg, K., Rousseau, A., "Analysis and Model Validation of the Toyota Prius Prime," SAE 2019-01-0369, SAE World Congress, Detroit, April 2019; Kim, N, Jeong, J., Rousseau, A. & Lohse-Busch, H. "Control Analysis and Thermal Model Development of PHEV," SAE 2015-01-1157, SAE World Congress, Detroit, April15; Kim, N., Rousseau, A. & Lohse-Busch, H. "Advanced Automatic Transmission Model Validation Using Dynamometer Test Data," SAE 2014-01-1778, SAE World Congress, Detroit, Apr. 14.; Lee, D. Rousseau, A. & Rask, E. "Development and Validation of the Ford Focus BEV Vehicle Model," 2014-01-1809, SAE World Congress, Detroit, Apr14; Kim, N., Kim, N., Rousseau, A., & Duoba, M. "Validating Volt PHEV Model with Dynamometer Test Data using Autonomie," SAE 2013-01-1458, SAE World Congress, Detroit, Apr. 13.; Kim, N., Rousseau, A., & Rask, E. "Autonomie Model Validation with Test Data for 2010 Toyota Prius," SAE 2012-01-1040, SAE World Congress, Detroit, Apr12; Karbowski, D., Rousseau, A, Pagerit, S., & Sharer, P. "Plug-in Vehicle Control Strategy - From Global Optimization to Real Time Application," 22th International Electric Vehicle Symposium (EVS22), Yokohama, (October 2006).

[503] Rousseau, A. Moawad, A. Kim, Namdoo. "*Vehicle System Simulation to Support NHTSA CAFE standards for the Draft Tar*." https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/anl-nhtsa-workshop-vehicle-system-simulation.pdf Last accessed Nov 20, 2019.

~~[504] [Cite docket ID]. Global later repeated that "only 18% of all vehicle data used as inputs to the ALPHA modeling was made available in the EPA's public sources. Additional data had to be specifically requested subsequent to the publication of the Draft TAR and Proposed Determination. This lack of publicly available data highlights transparency concerns which Global Automakers has raised on several previous occasions."~~

~~[505] Section 86.107 Dynamometer calibration.~~

In addition, the agencies disagree with UCS' comment that EPA's direct control over its effectiveness modeling and interface to OMEGA results in a more up-to-date analysis. In addition to Autonomie's continuous updates to incorporate the latest fuel-economy-improving technologies, discussed further below, the data supplied to and generated by Autonomie for use in the CAFE model was continuously updated during the analysis process. This is just one part of the iterative quality assurance (QA) and quality check (QC) process that the agencies developed when ANL's large-scale simulation modeling based in Autonomie was first used for the Draft TAR. In fact, ANL's high performance computing (HPC) platform allows a full set of simulations—over 750,000 modeled vehicles that incorporate over 50 different fuel-economy-improving technologies—to be simulated in one week. Subsets of the simulations can be re-run should issues come up during QA/QC in a day or less. Tools like the internet and high performance computers have allowed the agencies to evaluate technology effectiveness with up-to-date inputs without the proximity of the computers and the people running them working as a detriment the analysis.

Commented [A176]: REVISE: This section's response should be focused on explaning why the Autonomie model is up-to-date (without unnecessarily and inaccurately denigrating EPA's work.) The portion here about HPC is not directly related to the comment, and could shifted to a discussion more directly relevant to the comment.

Moreover, ANL's participation in developing inputs for the rulemaking analysis allowed the agencies access to vehicle benchmarking data from more vehicles than if the agencies were limited by their own resources, and access to the ANL staff's extensive experience based on direct coordination with vehicle manufacturers, suppliers, and researchers that all actively use Autonomie for their own work.

Finally, GEM, ALPHA, and Autonomie were all developed in the MATLAB computational environment as forward-looking physics-based vehicle models. Just as ALPHA has roots in GEM, created in 2010 to accompany the agencies' heavy-duty vehicle CO_2 emissions and fuel consumption standards, Autonomie has its origins in the software PSAT, and ADVISOR before that, developed over 20 years ago. Further, NHTSA's acceptance of GEM results for compliance with heavy-duty fuel economy regulations has no bearing on the decision to use Autonomie to assess the effectiveness of light-duty fuel economy and CO_2 improving technologies. GEM was developed to serve as the compliance model for heavy-duty vehicles,[506] and GEM serves that limited scope very well. However, GEM was not developed to assess, nor is it suitable for assessing the effectiveness of light-duty vehicle technologies. If it were, there would be no need for EPA to create and develop the ALPHA model. ~~Examples of GEM I limitations include:~~

- ~~GEM only requires up to five inputs from the user, and all the other parameters and their inputs are predefined (for Heavy-Duty Phase 1 compliance);~~
- ~~Only the agencies' pre-specified engine fuel maps are used;~~
- ~~Engine control is simplified, with no fuel cut-off feature during deceleration;~~
- ~~There is no capability to simulate electrified vehicles;~~
- ~~Only manual transmissions are used in the model for all vehicle simulations, which, while suitable for the Heavy-Duty Phase 1 program that did not include~~

[506] Newman, K., Dekraker, P., Zhang, H., Sanchez, J. et al., "Development of Greenhouse Gas Emissions Model (GEM) for Heavy- and Medium-Duty Vehicle Compliance," SAE Int. J. Commer. Veh. 8(2):2015, doi:10.4271/2015-01-2771.

~~transmission improvements, is inadequate for the vast majority of light-duty vehicles that have automatic transmissions; and~~

- ~~The model did not include engine torque interruption during gear shifting.~~

~~These limitations of GEM 1 were acceptable for heavy-duty Phase 1 compliance because compliance only required five inputs from manufacturers. However, this tool is insufficient for modeling and simulating light-duty vehicle technologies because of, among other reasons, the number of technologies available to improve light-duty vehicle fuel economy and the diversity of vehicle types to which those technologies could be applied.~~

Commented [A177]: No one, least of all UCS, is stating that GEM itself should be used for LD modeling, so this section seems irrelevant.

Commented [A178]: **DELETE:** It is not necessary to discussion limitations of the GEM model in order to respond to comments. Commenters are not suggesting that GEM by itself would be used for light-duty modeling, so this text is both non-responsive and unneecessary.

UCS did comment that full vehicle simulation could significantly improve the estimates of technology effectiveness, but thought it critical that the process be as open and transparent as possible. UCS pointed to ALPHA results published in peer-reviewed journals as an example of how transparency has provided the ALPHA modeling effort with significant and valuable feedback, and contrasted what they characterized as Autonomie's "black box" approach, which they stated "does not lend itself to similar dialog, nor does it make it easy to assess the validity of the results." Specifically, UCS stated that it is "impossible to verify, replicate, or alter the work done by Autonomie due to the expensive nature of the tools used and lack of open source or peer-reviewed output." In contrast, UCS stated that EPA's ALPHA model has been thoroughly peer reviewed, and is readily "downloadable, editable, and accessible to anyone with a MATLAB license."

The agencies responses on the merits of how ALPHA and Autonomie were peer-reviewed are discussed above. Regarding UCS' comment that it is impossible to verify, replicate, or alter the work done by Autonomie, the agencies disagree. All inputs, assumptions, model documentation – including of component models and individual control algorithms—and outputs for the NPRM Autonomie modeling were submitted to the docket for review.[507] Commenters were able to provide a robust analysis of Autonomie's technology effectiveness inputs, input assumptions, and outputs, as shown by their comments on specific vehicle

[507] NHTSA-2018-0067-1855. ANL Autonomie Compact Car Vehicle Class Results. Aug 21, 2018.
NHTSA-2018-0067-1856. ANL Autonomie Performance Compact Car Vehicle Class Results. Aug 21, 2018.
NHTSA-2018-0067-1494. ANL Autonomie Midsize Car Vehicle Class Results. Aug 21, 2018.
NHTSA-2018-0067-1487. ANL Autonomie Performance Pick-Up Truck Vehicle Class Results. Aug 21, 2018.
NHTSA-2018-0067-1663. ANL Autonomie Performance Midsize Car Vehicle Class Results. Aug 21, 2018.
NHTSA-2018-0067-1486. ANL Autonomie Small SUV Vehicle Class Results. Aug 21, 2018
NHTSA-2018-0067-1662. ANL Autonomie Performance Midsize SUV Vehicle Class Results. Aug21, 2018.
NHTSA-2018-0067-1661. ANL Autonomie Pickup Truck Vehicle class Results. Aug 21, 2018.
NHTSA-2018-0067-1485. ANL Autonomie Small Performance SUV Vehicle Class Results. Aug 21, 2018
NHTSA-2018-0067-1492. ANL Autonomie Midsize SUV Vehicle Class Results. Aug. 21, 2018.
NHTSA-2018-0067-0005. ANL Autonomie Model Assumptions Summary. Aug 21, 2018.
NHTSA-2018-0067-0003. ANL Autonomie Summary of Main Component Assumptions. Aug 21, 2018.
NHTSA-2018-0067-0007. Islam, E. S, Moawad, A., Kim, N, Rousseau, A. "*A Detailed Vehicle Simulation Process To Support CAFE Standards 04262018 – Report*" ANL Autonomie Documentation. Aug 21, 2018.
NHTSA-2018-0067-0004. ANL Autonomie Data Dictionary. Aug 21, 2018.
NHTSA-2018-0067-1692. ANL BatPac Model 12 55. Aug 21, 2018.
NHTSA-2018-0067-12299. Preliminary Regulatory Impact Analysis (July 2018). Posted July 2018 and updated August 23 and October 16, 2018.

technology effectiveness assumptions, discussed throughout this section and in the individual technology sections below.

The agencies also disagree with UCS' assessment of Autonomie as "expensive." While Autonomie is a commercial product, the biggest financial barrier to entry for both ALPHA and Autonomie is the same: a MATLAB license.[508,509] Regardless, ANL has made the version of Autonomie used for this final rule analysis available upon request, including the individual runs used to generate each technology effectiveness estimate.[510]

Commented [A179]: REVISE: The footnote here is a license request. As an alternative approach, EPA suggests that the actual run files be docketed, even if they can only be accessed with a paid-license to the Autonomie software. Otherwise, stakeholders may not have ready and convenient access to the runs used.

Next, ICCT supplanted its statement that the agencies "inexplicably" abandoned ALPHA, commenting that the agencies' explanation and justification for relying on Autonomie rather than ALPHA failed to discuss ALPHA in detail, and the agencies did not compare and contrast the two models. ICCT continued, "the EPA cannot select its modeling tool arbitrarily, yet it appeared that the EPA has whimsically shifted from an extremely well-vetted, up-to-date, industry-grade modeling tool to a less-vetted, academic-grade framework with outdated inputs without even attempt to scrutinize the change." ICCT also stated that the agencies are legally obligated to acknowledge and explain when they change position, and "cannot simply ignore that EPA previously concluded that the ALPHA modeling accurately projected real-world effects of technologies and technology packages."

The agencies disagree that a more in-depth discussion of ALPHA was required in the NPRM. In acknowledging the transition to using Autonomie for effectiveness modeling and the CAFE model for analysis of regulatory alternatives,[511] the agencies described several analytical needs that using a single analysis from the CAFE model –with inputs from the Autonomie tool—addressed. These included that Autonomie produced realistic estimates of fuel economy levels and CO_2 emission rates through consideration of real-world constraints, such as the estimation and consideration of performance, utility, and driveability metrics (e.g., towing capability, shift busyness, frequency of engine on/off transitions).[512] That EPA previously concluded the ALPHA modeling accurately projected real-world effects of technologies and technology packages has no bearing on Autonomie's ~~unique~~ ability to fulfill the analytical needs that the agencies articulated in the NPRM, including that Autonomie also accurately projects real-world effects of technologies and technology packages.

Commented [A180]: CHANGE AS SHOWN: "Unique" is over-stating the case, particularly when ALPHA will work just as well.

~~The agencies also disagree with ICCT's characterization of ALPHA as "an extremely well-vetted, up-to-date, industry-grade modeling tool" and Autonomie as a "less-vetted, academic-grade framework with outdated inputs." Again, Autonomie has been used by~~

Commented [A181]: DELETE: The explanation in the previous paragraph is sufficient to explain the selection of the Autonomie model. An inaccurate and unnecessary denigration of EPA's work is unnecessary and unhelpful to make explain the rationale of the EPA Administrator.

[508] *Autonomie. Frequently Asked Questions.* "Which version of matlab can I use?" https://www.autonomie.net/faq.html#faq2. Last accessed Nov. 19, 2019.
[509] EPA ALPHA v2.2 Technology Walk Samples. "*Running this version of ALPHA requires Matlab/Simulink with StateFlow 2016b.*" https://www.epa.gov/regulations-emissions-vehicles-and-engines/advanced-light-duty-powertrain-and-hybrid-analysis-alpha.
[510] Argonne Nationally Laboratory. Autonomie License Information. https://www.autonomie.net/asp/LicenseRequest.aspx. Last accessed Nov, 18, 2019.
[511] 83 FR 43000 (Aug. 24, 2018).
[512] 83 FR 43001 (Aug. 24, 2018).

~~government agencies, vehicle manufacturers (and by agencies and manufacturers together in the collaborative government-industry partnership U.S. DRIVE program), suppliers, and other organizations because of its ability to simulate many powertrain configurations, component technologies, and vehicle-level controls over numerous drive cycles. Characterizing ALPHA as an "industry-grade modeling tool" contravenes EPA's own description of its tool – an in-house vehicle simulation model used by EPA, not intended to be a commercial product.[344]~~

~~That characterization also contravenes documentation from the automotive industry indicating that manufacturers consider ALPHA to generate overly optimistic effectiveness values, to be unrepresentative of real-world constraints, and a difficult tool to use.[344-345] The Alliance commented to the MTE reconsideration that "[p]revious comments from the Alliance and individual manufacturers to the MTE docket have highlighted multiple concerns with EPA's ALPHA model. Many of these concerns remain unresolved."[346] Furthermore, the Alliance commented that ALPHA "has not been documented with any instructions making it difficult for users outside of EPA to run and interpret the model."[347] Global Automakers further stated that the "lack of publicly available data [related to inputs used in the ALPHA modeling] highlights transparency concerns, which Global Automakers has raised on several previous occasions."[348] In fact, both the Alliance of Automobile Manufacturers and Global Automakers, the two trade organizations that represent the automotive industry, concluded that Autonomie should be used to generate effectiveness inputs for the CAFE model.[349]~~

~~[344] See, e.g., Overview of ALPHA Model, http://www.epa.gov/regulations-emissions/vehicles-and-engines/advanced-light-duty-powertrain-and-hybrid-analysis/alpha; ALPHA Effectiveness Modeling: Current and Future Light-Duty Vehicle & Powertrain Technologies (Jan. 29, 2014), available at https://www.epa.gov/sites/production/files/2016-10/documents/alpha-model-see-gov't-ind-mtg-2016-01-20.pdf ("ALPHA is not a commercial product (e.g., there are no user manuals, tech support hotlines, graphical user interfaces, or full libraries of components)."). See also Peer Review of ALPHA Full Vehicle Simulation Model, available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100PLKL.pdf. While ALPHA peer-reviewers found the model to be a "fairly simple transparent model . . . [t]he model execution requires an expert Matlab Simulink user since no user-friendly interface currently exists." Indeed, EPA noted in response to this comment that "[a]s with any internal tool, EPA does not have the need for a 'user-friendly interface' like one that would normally accompany a commercial product which is available for purchase and fully supported for wide external usage."~~

~~[345] See, EPA-HQ-OAR-2015-0827-10125, at 7. As part of their assessment that known technologies could not meet the original MY 2022-2025 standards, Toyota noted that the ALPHA conversion of Toyota's MY 2015 to MY 2025 performance "appears to yield overly optimistic results because the powertrain efficiency curves represent best-case targets and not the average vehicle, the improved performance constraints are unmatchable, and the generated credits are out of sync with product cadence and design cycles." See also NHTSA-2010-0087-12431, at 7. More recently, Toyota stated in their comments to the NPRM that "Toyota's position [on the efficacy of the GM GA and LPM models] has been clearly represented by comments previously submitted by the Alliance of Automobile Manufacturers, Global Automakers, and Novation Analytics. These comments identify the LPM and GM GA models as sources of inaccuracy in EPA technology evaluations and provide suggested improvements. Neither model is transparent, intuitive, or user friendly."~~

~~[346] EPA-HQ-OAR-2015-0827-0194.~~

~~[347] EPA-HQ-OAR-2015-0827-0194, at 33.~~

~~[348] EPA-HQ-OAR-2015-0827-0194.~~

~~[349] EPA-HQ-OAR-2015-0827-0723.~~

~~[350] EPA-HQ-OAR-2015-0827-0763 at 5. ("EPA should abandon the lumped-parameter model and instead use NHTSA's Autonomie and Volpe models to support the Revised Final Determination."). See also EPA-HQ-OAR-~~

In addition, Autonomie contains ~~more up-to-date~~ submodels to represent the latest electrification and advanced transmission and advanced engine technologies. As summarized by the Alliance, "Autonomie was developed from the start to address the complex task of combining 2 power sources in a hybrid powertrain. ~~However, [ALPHA] has not been validated or used to simulate hybrid powertrains.~~"[520] Autonomie has continuously improved over the years by adopting new technologies into its modeling framework. Even a small sampling of SAE papers shows how Autonomie has been validated to simulate the latest fuel-economy-improving technologies like hybrid vehicles and PHEVs.[521]

Commented [A182]: CHANGE AS SHOWN: The comparison to EPA models an inputs is unnecessary, and not factually correct considering the full range of EPA's benchmarking efforts, both previously and more recently.

Moreover, Autonomie effectively considers other real-world constraints faced by the automotive industry. Vehicle manufacturers and suppliers spend significant time and effort to ensure technologies are incorporated into vehicles in ways that will balance consumer acceptance for attributes such as driving quality,[522] noise-vibration-harshness (NVH), and meeting other regulatory mandates, like EPA's and CARB's On-Board Diagnostics (OBD) requirements,[523] and EPA's and CARB's criteria exhaust emissions standards.[524] The implementation of new fuel economy improving technologies have at times raised consumer acceptance issues.[525] As discussed earlier, there are diminishing returns for modeling every vehicle attribute and tradeoff, as each takes time and incurs cost; however, Autonomie sub-models are designed to account for a number of the key attributes and tradeoffs, so the resulting effectiveness estimates reflect these real world constraints.

Furthermore, aside from the fact that Autonomie represents the structural state-of-the-art in full-vehicle modeling and simulation, Autonomie can be populated with any inputs that could be populated in the ALPHA model.[526] The agencies chose to use specific inputs for this rulemaking because, as discussed further in Sections [xxx] below, they best represent the technologies that manufacturers could incorporate in the rulemaking timeframe, in a way that balanced important concerns like consumer acceptance. Some other examples of how Autonomie inputs have been updated with the latest vehicle technology data specifically for this

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~~2015-0827-9728 at 15 (stating the EPA's engine mapping and tear down analyses "should be integrated into the Autonomie model, which then feeds into the Volpe modeling process."), EPA-HQ-OAR-2015-0827-9194 at 33, "Alliance, [Docket ID]~~

[521] Jeong, J., Kim, N., Stutenberg, K., Rousseau, A., "Analysis and Model Validation of the Toyota Prius Prime," SAE 2019-01-0369, SAE World Congress, Detroit, April 2019; Kim, N, Jeong, J. Rousseau, A. & Lohse-Busch, H. "Control Analysis and Thermal Model Development of PHEV," SAE 2015-01-1157.

[522] An example of a design requirement is accommodating the "lag" in torque delivery due to the spooling of a turbine in a turbocharged downsized engine. This affects real-world vehicle performance, as well as the vehicle's ability to shift during normal driving and test cycles.

[523] EPA adopted and incorporated by reference current OBD regulations by the California ARB, effective for MY 2017, that cover all vehicles except those in the heavier fraction of the heavy-duty vehicle class.

[524] Tier 3 emission standards for light-duty vehicles were proposed in March 2013 78 FR 29815 (May 21, 2013) and signed into law on March 3, 2014 79 FR 23413 (June 27, 2014). The Tier 3 standards—closely aligned with California LEV III standards—are phased-in over the period from MY2017 through MY2025. The regulation also tightens sulfur limits for gasoline.

[525] Atiyeh, C. *"What you need to know about Ford's PowerShift Transmission Problems"* Car and Driver, July 11, 2019. https://www.caranddriver.com/news/a27438193/ford-powershift-transmission-problems/.

[526] For example, Autonomie used the HCR1 and HCR2 engine maps used as inputs to ALHPA in the Draft TAR and Proposed Determination.

analysis include test data incorporated from both ANL and NHTSA-sponsored vehicle benchmarking, including an updated automatic transmission skip-shifting feature,[527] additional application of cylinder deactivation for turbocharged downsized engines, and as discussed above, new modeling and simulation that includes variable compression ratio and Miller Cycle engines.

Finally, ICCT commented that the agencies must conduct a systematic comparison of the Autonomie modeling system and ALPHA modeling in several respects, including the differences in technical inputs and resulting efficiency estimates, to explain how the choice of model altered the regulatory technology penetration and compliance cost estimations, and the differences in modeling methodologies, including regarding the relative level of experience of the teams conducting the effectiveness modeling, to demonstrate that the choice to use Autonomie was not "due to convenience and easier access by the NHTSA research team, rather than for any technical improvement." ICCT stated that without performing this comparison, "it otherwise appears that the agencies switched from a better-vetted model and system of inputs with more recent input data to a less-vetted model and system of inputs as a way to bury many dozens of changes without transparency or expert assessment (as illustrated in the above errors and invalidated data on individual technologies)." Each issue is discussed below in turn.

First, regarding technical inputs, technology pathways, and resulting outputs, ICCT stated that the agencies must compare (1) whether the models have been routinely strengthened by incorporating cutting edge 2020-2025 automotive technologies to ensure they reflect the available improvements; (2) every efficiency technology in the 2016 Draft TAR and original EPA TSD and Proposed and Final Determination analysis against the NPRM; (3) all the major technology package pathways (i.e., all combinations with high uptake in the Adopted and Augural 2025 standards) in the current NPRM versus the 2016 Draft TAR and the 2016 TSD and original Final Determination analysis; (4) each of the major 2025 technology package synergies; (5) the modeling work of EPA's, Ricardo's, and Argonne's 2014-2018 model year engine benchmarking and modeling of top engine and transmission models; and "defend why they appear to have chosen to dismiss the superior and better vetted technology modeling approach."

ICCT stated that the agencies must make these comparisons because, "[o]therwise, it seems obvious that the agencies have subjectively decided to use the modeling that increases the modeled cost, providing further evidence of a high degree of bias without an objective accounting of the methodological differences and the sensitivity of the results to their new decision." Moreover, ICCT stated that "[b]ecause ALPHA is the dominant, preferred, and better-vetted modeling and was used in the original Proposed and Final Determination, the agencies are responsible for assessing and describing how the use of the ALPHA modeling would result in a different regulatory result for their analysis of the 2017-2025 adopted CO_2 and Augural CAFE standards."

The agencies do not believe that it is necessary to conduct a retrospective comparison of ALPHA/LPM and Autonomie effectiveness for every technology in the Draft TAR and Proposed Determination to the NPRM and final rule analyses, between the two models for technologies

[527] NHTSA Benchmarking, "Laboratory Testing of a 2017 Ford F-150 3.5 V6 EcoBoost with a 10-speed transmission." DOT HS 812 520.

and packages used in the NPRM and final rule analysis, or to explain where and why Autonomie provided different results from ALPHA and the LPM. Most importantly, ICCT's stated purpose for this comparison—to assess and describe how the use of the ALPHA modeling would result in a different regulatory result of CAFE and CO_2 standards—inappropriately conflates the tools used to model technology effectiveness with the ultimate regulatory result.

To be clear, neither ALPHA or Autonomie (nor the inputs, input assumptions used to populate the models, nor their modeling outputs) dictate any particular regulatory outcome, rather, they present information to assist decisionmakers in weighing and balancing factors to set appropriate standards. In this case, the agencies believe that it was reasonable to consider effectiveness estimates developed with Autonomie~~, because, simply put, in addition to having capabilities that ALPHA does not have, Autonomie performs its core functions better~~.

To demonstrate, in addition to everything discussed previously in this section, differences in how each model handles powertrain systems modeling with specific examples are discussed below as a reference, and differences between the agencies' approaches to effectiveness modeling for specific technologies is discussed in Section [xxx] where appropriate. While the improved approach to estimating technology effectiveness estimates certainly impacted the regulatory technology penetration, compliance cost estimates, and "major 2025 technology packages and synergies," how technologies are applied in the compliance modeling and the associated costs of the technologies is equally as important to consider when examining factors that might impact the regulatory analysis; that consideration goes beyond the scope of simply considering which full vehicle simulation model better performs the functions required of this analysis.

The agencies have discussed updates to the technologies considered in the Autonomie modeling throughout this section, in addition to Autonomie's models and submodels that control advanced technologies like hybrid and electrified powertrains. ~~While the ALPHA model has only recently developed simulations and model controls to represent a basic 48V BISG mild hybrid vehicle using ANL test data in 2018,[528]~~ Autonomie's explicit models, submodels, and controls for hybrid and electric vehicles have been continuously validated over the past several years,[529] as Autonomie was developed from the beginning to address the complex task of

Commented [A183]: REVISE: This is non-responsive to the comment. The argument by ICCT is that the CAFE model, and associated inputs, significantly inflates the costs of attaining specific standards. Since cost is a significant factor in the selection of final standards, it's not unreasonable to infer that estimating higher costs would result in a selection of less stringent standards. Arguing that ICCT thinks the CAFE model makes the decision rather than the Administrator is sidestepping the issue, as well as being needlessly speaking down toto the commenter.

Commented [A184]: DELETE: This has not been established, and in any case, the denigration of the ALPHA model relative to Autonomie is unnecessary.

Commented [A185]: DELETE: That is not factualy correct. EPA has developed and validated MatLab Simulink modules that model modern Li-ion batteries, BISG systems, P2 systems, and PowerSplit systems, all for the purposes of extending the functionality of ALPHA for HEV modeling.

EPA published papers on powersplit and P2 strong hybrids in 2013, which were shared with NHTSA at that time. The citations are:

Lee, SoDuk, Byungho Lee, Joseph McDonald, L. James Sanchez, and Edward Nam. Modeling and Validation of Power-Split and P2 Parallel Hybrid Electric Vehicles. No. 2013-01-1470. SAE Technical Paper, 2013.

Lee, SoDuk, Byungho Lee, Joseph McDonald, and Edward Nam. Modeling and validation of lithium-ion automotive battery packs. No. 2013-01-1539. SAE Technical Paper, 2013.

~~[528] Lee, S., Cherry, J., Safoutin, M., McDonald, J. et al., "Modeling and Validation of 48V Mild Hybrid Lithium-Ion Battery Pack," SAE Int. J. Alt. Power. 7(3):273-287, 2018, https://doi.org/10.4271/2018-01-0133; Lee, S., Cherry, J., Safoutin, M., Nam, A. et al., "Modeling and Controls Development of 48 V Mild Hybrid Electric Vehicles," SAE Technical Paper 2018-01-0113, 2018, https://doi.org/10.4271/2018-01-0113.~~

[529] Karbowski, D., Kwon, J., Kim, N., & Rousseau, A., "Instantaneously Optimized Controller for a Multimode Hybrid Electric Vehicle," SAE paper 2010-01-0816, SAE World Congress, Detroit, April 2010; Sharer, P., Rousseau, A., Karbowski, D., & Pagerit, S. "Plug-in Hybrid Electric Vehicle Control Strategy - Comparison between EV and Charge-Depleting Options," SAE paper 2008-01-0460, SAE World Congress, Detroit (April 2008); and Rousseau, A., Shidore, N., Carlson, R., & Karbowski, D. "Impact of Battery Characteristics on PHEV Fuel Economy," AABC'08; Jeong, J., Kim, N., Stutenberg, K., Rousseau, A., "Analysis and Model Validation of the Toyota Prius Prime," SAE 2019-01-0369, SAE World Congress, Detroit, April 2019; Kim, N, Jeong, J. Rousseau, A. & Lohse-Busch, H. "Control Analysis and Thermal Model Development of PHEV," SAE 2015-01-1157, SAE World Congress, Detroit, April15; Lee, D. Rousseau, A. & Rask, E. "Development and Validation of the Ford Focus BEV Vehicle Model," 2014-01-1809, SAE World Congress, Detroit, Apr14; Kim, N., Kim, N., Rousseau, A., &

combining two power sources in a hybrid powertrain. ~~So, not only has Autonomie been "routinely strengthened by incorporating cutting edge 2020-2025 automotive technologies to ensure they reflect the available improvements." Autonomie's models, submodels, and controls were validated for these technologies even before they were incorporated in ALPHA.~~

Also regarding the inputs to both models, as highlighted in Section [xxx], and discussed above, inputs and assumptions for the ALPHA modeling used for the EPA Draft TAR and Proposed Determination analysis were projected from benchmarking testing. ~~While it is straightforward to measure engine fuel consumption and create an engine fuel map, it is extremely challenging to identify the specific technologies and levels of technologies present on a benchmarking engine. Attributing changes in the overall engine fuel consumption to the individual engine technologies that make up the complete engine involves significant uncertainty.~~

~~The fixed-point model approach used by the ALPHA model does not develop an effectiveness function and assigns a single value to a technology. The single value is derived from benchmark testing, which often does not isolate the effect of a single technology from the effects of other technologies on the tested vehicle. To isolate a single technology's effect for use in fixed-point modeling properly, the agencies would need to benchmark multiple versions of a single vehicle, carefully controlling changes to the vehicles' fuel efficiency technologies. This process would need to be repeated for a large portion of the vehicle fleet and would require significant funding and thousands of lab hours to complete. Without this level of data, fixed-point effectiveness estimates tend to be too high, as they are unable to account for synergetic effects of multiple technologies. Specifically, when EPA benchmarks vehicles like the 2018 Toyota Camry, the resulting fuel map captures the benefits of many technologies associated with that vehicle, and not just the engine. This data can be helpful when developing controls and validating component operations in modeling, but it is inaccurate to conclude the fuel consumption is directly related to specific engine technologies.~~

~~Contrasted,~~ The NPRM and final rule Autonomie analyses selected specific base engine maps and applied technologies incrementally, both individually and in known combinations, to better isolate the impacts of the technologies. As discussed above, this also implemented NAS Recommendation 2.1, to use engine-model-generated maps in the full vehicle simulations derived from a validated baseline map in which all parameters except the new technology of interest are held constant.[530]

~~As another representative example of a specific model behavior or implementation that might provide a difference in simulation results, the agencies compared ALPHA and Autonomie transmission shifting events for a Toyota Camry, to highlight the differences in how each model handles transmission shift logic. For reference, ALPHA uses a fixed shift map to decide upshift~~

Duoba, M. "Validating Volt PHEV Model with Dynamometer Test Data using Autonomie," SAE 2013-01-1458, SAE World Congress, Detroit, Apr. 13.; Kim, N., Rousseau, A., & Rask, E. "Autonomie Model Validation with Test Data for 2010 Toyota Prius," SAE 2012-01-1040, SAE World Congress, Detroit, Apr12; Karbowski, D., Rousseau, A, Pagerit, S., & Sharer, P. "Plug-in Vehicle Control Strategy - From Global Optimization to Real Time Application," 22th International Electric Vehicle Symposium (EVS22), Yokohama, (October 2006).

[530] 2015 NAS Report at 82.

Commented [A186]: DELETE: The EPA approach for modeling hybrids is not relevant to the development of Autonomie discussed here.

Commented [A187]: DELETE: When read out of context, the actual statement made is factual – it IS challenging to appropriately assign the benefits of specific technologies from engine testing. But EPA's process does not attempt to break-down individual sub-component effectiveness estimates from the benchmarked engine. We just use to actual package of engine technologies as a whole. So the point is moot.

Commented [A188]: DELETE: Not sure what the point of this paragraph is. It seems to be saying that running a series of simulations with different technology packages is not an appropriate way to determine effectiveness, but that's the same thing that Autonomie does.

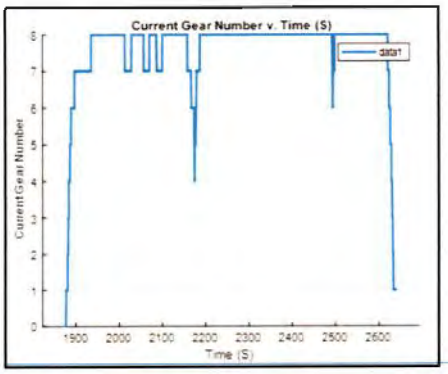
Ignoring the actual text, what this might be attempting to say is that using simulated, add-one-tech-at-a-time engine maps is superior to using real engine maps? Although using simulated maps is not unreasonable, the drawback is that the simulated packages could diverge from real life as errors accrue, and in that sense using data from actual engines is preferable.

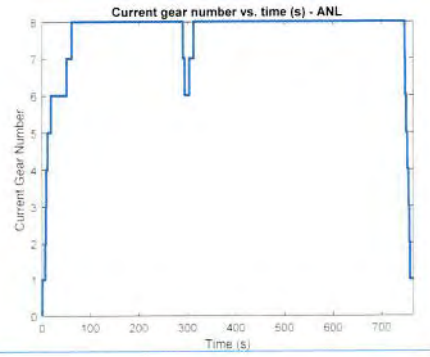
Commented [A189]: DELETE: This is a mischaracterization of EPA's work, and implies that EPA used vehicle-level benchmarking to estimate Camry engine performance. Apparently the author believes EPA engine data (including the Camry data) is developed from two-cycle test numbers. If so, that's factually incorrect, as can be seen by reading EPA's published paper: [Ref SAE paper 2019-01-0249 if interested on Toyota engine data]

The paper describes that the engine was tested on an engine dynamometer. EPA individually instrumented the valvetrain to directly measure and completely map the valve events and we have full mapping of cylinder-pressure based heat release, combustion phasing, EGR rates, variation of the effective compression ratio, COV of IMEP, etc., etc. COV of IMEP (which can't be modeled within GT-POWER, and without which there is no true way to tune EGR and spark timing within IAV's modeled maps.)

Commented [A190]: DELETE: This is completely false. EPA has previously published SAE papers on dynamic shift algorithm ('ALPHAshift, SAE Int. J. Engines 8(3):2015)

~~and downshift events, and Autonomie uses validated algorithms developed from dynamometer test data that adapts the shifting map to specific engine and transmission combinations to maximize fuel efficiency while maintaining drive quality. Figure VI-5 below compares the shifting logic from ALPHA (left) and Autonomie (right). The difference in calibration, which can be traced to factors like maintaining engine speed in the best fuel consumption zone, would lead to a different effectiveness impact. In general, while aggressive shifting logic does lead to higher vehicle fuel efficiency, aggressive shifting causes shift busyness which is not acceptable to consumers because it is perceived as abnormal transmission behavior and also may increase noise, vibration, and harshness (NVH).~~



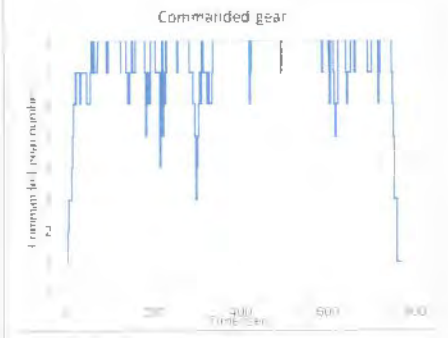


~~Figure VI-5 – Comparison of Toyota Camry shifting events between ALPHA (left) and Autonomie (right) for the HWFET[541]~~

Regarding the technical expertise of the team conducting the effectiveness modeling, ICCT commented:

> [T]he agencies should also disclose how much commercial business is conducted by the Ricardo, IAV, and Argonne Autonomie teams that underpin the modeling of EPA and NHTSA, respectively, including how much related research they have done for auto industry clients over the past ten years. We mention this because we strongly suspect that Ricardo, upon which EPA built its ALPHA model, has done at least an order of magnitude (in number of projects, person-hours, and budget) more work with and for the automotive industry than the IAV and Autonomie teams have in direct work for automotive industry clients. A conventional government procurement effort that competitively vets potential research expert teams would presumably have selected for such automotive industry credentials and experience, yet it appears that the agencies are wholly deferring to Autonomie's less rigorous research-grade modeling framework and data due to convenience and easier access by the NHTSA research team, rather than for any technical improvement, and this is to the detriment of showing clear understanding of

Commented [A191]: DELETE: Innaccurate and unnecessary denigration of EPA's work. Specifically, this paragraph appears to be arguing that the Autonomie shift logic is superior to ALPHA's because it simulates fewer shifts for the Camry. However, actual test data for this vehicle shows an extremely poor match between Autonomie simulations and real data, so the point of this paragraph is not valid.. (actual test data for an eight-speed Toyota Camry over the HWFET. Shown in comment bubble.)



~~[541] ALPHA v2.2 Technology Walk Samples. Jan. 12, 2017. https://www.epa.gov/sites/production/files/2017-01/alpha-20170112.zip Last Accessed Dec 9, 2019.~~

real-world automotive engineering developments (as demonstrated by many erroneous technology combination results throughout these comments).

First, NHTSA follows Federal Acquisition Regulation (FAR) to award contracts and Interagency Agreements (IAAs),[532] and any awarded contracts and IAAs must follow the FAR requirements. Importantly, FAR 3.101-1 includes key aspects of conduct and ethics that NHTSA must follow in awarding a contract or IAA:

Government business shall be conducted in a manner above reproach and, except as authorized by statute or regulation, with complete impartiality and with preferential treatment for none. Transactions relating to the expenditure of public funds require the highest degree of public trust and an impeccable standard of conduct. The general rule is to avoid strictly any conflict of interest or even the appearance of a conflict of interest in Government-contractor relationships. While many Federal laws and regulations place restrictions on the actions of Government personnel, their official conduct must, in addition, be such that they would have no reluctance to make a full public disclosure of their actions.

While some factors are more relevant than others in considering whether to award a contract or enter into an IAA, the amount of work that an organization has performed, characterized by projects, person-hours, and budget, is only one of a multitude of factors that is considered (if it is even considered at all an agency might not request this information and an organization might decline to provide it because of contractual clauses or to protect commercial business interests) when assessing whether an organization meets the agency's needs for a specific task. Other factors, such as the federal budget, also set boundaries for the scope of work that can be performed under any competitive government procurement effort.

As discussed throughout this section, the team at Argonne National Laboratory behind Autonomie has developed and refined a state-of-the-art tool that is used by the automotive industry, government agencies, and research or other nongovernmental institutions around the world. The tool has been and continues to be validated to production vehicles, and updated to include models, submodels, and controls representing the state-of-the-art in fuel economy improving technology. To the extent that ICCT believes that "research done for auto industry clients," "work with and for the automotive industry," and "automotive industry credentials and experience," are metrics upon which to base this type of important decision, the agencies point ICCT to the statements from the automotive industry, above, recommending Autonomie be used for technology effectiveness modeling. ICCT can rest assured that the merits of all potential approaches to estimating technology effectiveness were thoroughly considered before ANL and the Autonomie tool were ultimately selected for this rulemaking.

Commented [A192]: REVISE: This tone is disparaging to the public commenter.

ICCT concluded that "[w]hile the agencies are in their process of conducting a proper vetting of their NPRM's foundational Autonomie-based modeling, we recommend that they rely on what appears to be the superior and better vetted technology modeling approach with more

[532] Federal Acquisition Regulation (FAR). https://www.acquisition.gov .

thorough and state-of-the-art advanced powertrain systems modeling and engine maps from the EPA ALPHA modeling."

The agencies properly vetted the Autonomie modeling and decided that Autonomie represented ~~the best~~a reasonable and appropriate tool to provide technology effectiveness estimates for this rulemaking. To the extent that commenters' concerns were more about the effectiveness results than the tools used to model technology effectiveness, modeling updates detailed in the Section [xxx], below, address those comments. While some commenters may still be dissatisfied with Autonomie's technology effectiveness estimates, the agencies believe that the refinement of inputs and input assumptions, and associated explanation of why those refinements are appropriate and reasonable, have appropriately addressed comments on these issues. Importantly, none of these refinements have led either agency to reconsider using Autonomie for this rulemaking analysis.

Commented [A193]: CHANGE AS SHOWN: EPA does not agree that Autonomie represents the "best" tool for GHG vehicle simulation; we recommend reverting to the NPRM language that the Administrator has determined it is a "reasonable and appropriate" tool under his CAA discretion.

Additional discussion of the agencies' decision to rely on one set of modeling tools for this rulemaking is located in Section [xxx] of this preamble.

c) Technology Effectiveness Values Implementation in the CAFE Model

While the Autonomie model produces a large amount of information about each simulation run—for a single technology combination, in a single technology class—the CAFE model only uses two elements of that information: battery costs (discussed in detail in Section [Battery Costs]), and fuel consumption on the city and highway cycles. We combine the fuel economy information from the two cycles to produce a composite fuel economy for each vehicle, on each fuel. Plug-in hybrids, being the only dual-fuel vehicles in the Autonomie simulation, require efficiency estimates of operation on both gasoline and electricity–as well as an estimate of the utility factor, or the number of miles driven on each fuel. The fuel economy information for each technology combination, for each technology class, is converted into a single number for use in the CAFE model.

Commented [A194]: REVISE: Add specific cross reference. Note that EPA has not seen this section – is it part of the RIA?

As described in greater detail below, each Autonomie simulation record represents a unique combination of technologies, and we create a technology "key" or technology state vector that describes all the technology content associated with a record. The 2-cycle fuel economy of each combination is converted into fuel consumption (gallons per mile) and then normalized relative to the starting point for the simulations. In each technology class, the combination with the lowest technology content is the VVT (only) engine, with a 5-speed transmission, no electrification, and no body-level improvements (mass reduction, aerodynamic improvements, or low rolling resistance tires). This is the reference point (for each technology class) for all the effectiveness estimates in the CAFE model. The improvement factors that the model uses are a given combination's fuel consumption improvement relative to the reference vehicle in its technology class.

For the majority of the technologies analyzed within the CAFE Model, the fuel economy improvements were derived from the database of Autonomie's detailed full-vehicle modeling and simulation results. In addition to the technologies found in the Autonomie simulation

database, the CAFE modeling system also incorporated a handful of technologies that were required for CAFE modeling, but were not explicitly simulated in Autonomie. The effectiveness of these technologies either could not be captured on the 2-cycle test, or there was no robust data that could be used as an input to the full-vehicle modeling and simulation, like with emerging technologies such as advanced cylinder deactivation (ADEAC). These additional technologies are discussed further in Sections [Technology Effectiveness] and [Individual Technologies]. For calculating fuel economy improvements attributable to these additional technologies, the model used defined fuel consumption improvement factors that are constant across all technology combinations in the database and scale multiplicatively when applied together. The Autonomie-simulated and additional technologies were then externally combined, forming a single dataset of simulation results (referred to as the vehicle simulation database, or simply, database), which may then be utilized by the CAFE modeling system.

To incorporate the results of the combined database of Autonomie-simulated and additional technologies, while still preserving the basic structure of the CAFE Model's technology subsystem, it was necessary to translate the points in this database into corresponding locations defined by the technology pathways. By recognizing that most of the pathways are unrelated, and are only logically linked to designate the direction in which technologies are allowed to progress, it is possible to condense the paths into a smaller number of groups based on the specific technology. In addition, to allow for technologies present on the Basic Engine and Dynamic Road Load (DLR—i.e., MASS, AERO, and ROLL) paths to be evaluated and applied in any given combination, a unique group was established for each of these technologies.

As such, the following technology groups are defined within the modeling system: engine cam configuration (CONFIG), VVT engine technology (VVT), VVL engine technology (VVL), SGDI engine technology (SGDI), DEAC engine technology (DEAC), non-basic engine technologies (ADVENG), transmission technologies (TRANS), electrification and hybridization (ELEC), low rolling resistance tires (ROLL), aerodynamic improvements (AERO), mass reduction levels (MR), EFR engine technology (EFR), electric accessory improvement technologies (ELECACC), LDB technology (LDB), and SAX technology (SAX). The combination of technologies along each of these groups forms a unique technology state vector and defines a unique technology combination that corresponds to a single point in the database for each technology class evaluated within the modeling system.

As an example, a technology state vector describing a vehicle with a SOHC engine, variable valve timing (only), a 6-speed automatic transmission, a belt-integrated starter generator, rolling resistance (level 1), aerodynamic improvements (level 2), mass reduction (level 1), electric power steering, and low drag brakes, would be specified as "SOHC; VVT; AT6; BISG; ROLL10; AERO20; MR1; EPS; LDB."[533] By assigning each unique technology combination a state vector such as the one in the example, the CAFE Model can then assign each vehicle in the analysis fleet an initial state that corresponds to a point in the database.

[533] In the example technology state vector, the series of semicolons between VVT and AT6 correspond to the engine technologies which are not included as part of the combination, while the gap between MR1 and EPS corresponds to EFR and the omitted technology after LDB is SAX. The extra semicolons for omitted technologies are preserved in this example for clarity and emphasis, and will not be included in future examples.

Once a vehicle is assigned (or mapped) to an appropriate technology state vector (from one of approximately three million unique combinations, which are defined in the vehicle simulation database as CONFIG; VVT; VVL; SGDI; DEAC; ADVENG; TRANS; ELEC; ROLL; AERO; MR; EFR; ELECACC; LDB; SAX), adding a new technology to the vehicle simply represents progress from a previous state vector to a new state vector. The previous state vector simply refers to the technologies that are currently in use on a vehicle. The new state vector, however, is computed within the modeling system by adding a new technology to the combination of technologies represented by the previous state vector, while simultaneously removing any other technologies that are superseded by the newly added one.

For example, consider the vehicle with the state vector described as: SOHC; VVT; AT6; BISG; ROLL10; AERO20; MR1; EPS; LDB. Assume the system is evaluating PHEV20 as a candidate technology for application on this vehicle. The new state vector for this vehicle is computed by removing SOHC, VVT, AT6, and BISG technologies from the previous state vector,[534] while also adding PHEV20, resulting in the following: PHEV20; ROLL10; AERO20; MR1; EPS; LDB.

From here, it is relatively simple to obtain a fuel economy improvement factor for any new combination of technologies and apply that factor to the fuel economy of a vehicle in the analysis fleet. The formula for calculating a vehicle's fuel economy after application of each successive technology represented within the database is defined, simply put, as the difference between the fuel economy improvement factor associated with the technology state vector before application of a candidate technology, and after the application of a candidate technology.[535] This is applied to the original compliance fuel economy value for a discrete vehicle in the MY 2017 analysis fleet, as discussed previously in Section [Technology Effectiveness].

The fuel economy improvement factor is defined in a way that captures the incremental improvement of moving between points in the database, where each point is defined uniquely as a combination of up to 15 distinct technologies describing, as mentioned above, the engine's cam configuration, multiple distinct combinations of engine technologies, transmission, electrification type, and various vehicle body level technologies.

Unlike the preceding versions of the modeling system, the current version of the CAFE Model relies entirely on the vehicle simulation database for calculating fuel economy improvements resulting from all technologies available to the system. The fuel economy improvements are derived from the factors defined for each unique technology combination or state vector. Each time the improvement factor for a new state vector is added to a vehicle's existing fuel economy, the factor associated with the old technology combination is entirely removed. In that sense, application of technologies obtained from the Autonomie database is

[534] For more discussion of how the CAFE Model handles technology supersession, see [CAFE Model Documentation].
[535] For more discussion of how the CAFE Model calculates a vehicle's fuel economy where the vehicle switches from one type of fuel to another, for example, from gasoline operation to diesel operation or from gasoline operation to plug-in hybrid/electric vehicle operation, see [CAFE Model Documentation].

"self-correcting" within the model. As such, special-case adjustments defined by the previous version of the model are not applicable to this one.

Meszler Engineering Services, commenting on behalf of Natural Resources Defense Council, commented that "[w]ith very limited exception, technology is not included in the NPRM CAFE model if it was not included in the simulation modeling that underlies the ANL database," citing the "add-on" technologies and technologies with fixed effectiveness values.[536] Meszler continued, "[t]his same limitation controls the coupling of technologies, and by extension the definition of the CAFE model technology pathways. If a combination of technologies were not modeled during the development of the ANL database, that package (or combination) of technologies is not available for adoption in the CAFE model. Both of these design constraints serve to limit the slate of technologies available to respond to fuel economy standards. The slate of available technologies is basically constrained to those included in NHTSA's research activity. If a technology or technology combination was not in the NHTSA research planning process, it is not available in the model." Finally, Meszler stated that "because of the constrained model architecture and the reliance on the ANL database for impact estimates, independently expanding the model to include additional technologies or technology combinations is not trivial."

We agree that expanding the database to include new technologies is not trivial. However, it is possible. The set of available technologies is part of the model code, and the code is made public upon each release of the model. Many commenters made modifications to the model code, conducted additional tests of their own, and presented their results to the agencies in the form of public comments before the end of the public comment period. A user could add the new technology, identify the associated engineering restrictions that determine combinations for which that technology should not be considered, and add the relevant rows (representing possible technology combinations that include the new technology) in the database (which exists locally on every computer that runs the model). An enterprising user could also take an existing technology along a given path and replace the efficiency values with new values–presumably from their own full vehicle simulations for each technology combination that contains the technology in question. Given the length of time and computing power required to simulate vehicle fuel economy on the test cycle for every possible combination that could be considered by the CAFE model, using a pre-defined database that represents a large ensemble of simulated technology combinations is preferable to the alternative of fully integrating a vehicle simulation model that would be required to run in real-time during the compliance simulation to evaluate the effectiveness of every combination considered (not just applied) by the model.

5. Technology Costs

In the proposal, the agencies estimated present and future costs for fuel-saving technologies, taking into consideration the type of vehicle, or type of engine if technology costs vary by application. These cost estimates are based on three main inputs. First, the agencies estimated direct manufacturing costs (DMCs), or the component and labor costs of producing and assembling the physical parts and systems, with estimated costs assuming high volume

[536] NHTSA-2018-0067-11723, at 4-5.

production. DMCs generally do not include the indirect costs of tools, capital equipment, financing costs, engineering, sales, administrative support or return on investment. Second, the agencies accounted for these indirect costs via a scalar markup of direct manufacturing costs (the retail price equivalent, or RPE). Finally, costs for technologies may change over time as industry streamlines design and manufacturing processes. The agencies therefore estimated potential cost improvements with learning effects (LE). The retail cost of equipment in any future year is estimated to be equal to the product of the DMC, RPE, and LE. Considering the retail cost of equipment, instead of merely direct manufacturing costs, is important to account for the real-world price effects of a technology, as well as market realities. Absent a government mandate, motor vehicle manufacturers will not undertake expensive development and production efforts to implement technologies without realistic prospects of consumers being willing to pay enough for such technology to allow for the manufacturers to recover their investment.

a) Direct Manufacturing Costs

Direct manufacturing costs (DMCs) are the component costs of the physical parts and systems that make up a complete vehicle. The analysis used agency-sponsored tear-down studies of vehicles and parts to estimate the DMCs of individual technologies, in addition to independent tear-down studies, other publications, and confidential business information. In the simplest cases, the agency-sponsored studies produced results that confirmed third-party industry estimates, and aligned with confidential information provided by manufacturers and suppliers. In cases with a large difference between the tear-down study results and credible independent sources, study assumptions were scrutinized, and sometimes the analysis was revised or updated accordingly.

Due to the variety of technologies and their applications, and the cost and time required to conduct detailed tear-down analyses, the agencies did not sponsor teardown studies for every technology. In addition, many fuel-saving technologies were considered that are pre-production, or sold in very small pilot volumes. For those technologies, a tear-down study could not be conducted to assess costs because the product is not yet in the marketplace for evaluation. In these cases, the agencies relied upon third-party estimates and confidential information from suppliers and manufacturers were relied upon; however, there are some common pitfalls with relying on confidential business information to estimate costs. The agencies and the source may have had incongruent or incompatible definitions of "baseline." The source may have provided DMCs at a date many years in the future, and assumed very high production volumes, important caveats to consider for agency analysis. In addition, a source, under no contractual obligation to the agencies, may provide incomplete and/or misleading information. In other cases, intellectual property considerations and strategic business partnerships may have contributed to a manufacturer's cost information and could be difficult to account for in the model as not all manufacturer's may have access to proprietary technologies at stated costs. The agencies carefully evaluated new information in light of these common pitfalls, especially regarding emerging technologies.

Specifically, the analysis used third-party, forward-looking information for advanced cylinder deactivation and variable compression ratio engines. While these cost estimates may be

preliminary (as is the case with many emerging technologies prior to commercialization), the agencies consider them to be reasonable estimates of the likely costs of these technologies.

While costs for fuel-saving technologies reflect the best estimates available today, technology cost estimates will likely change in the future as technologies are deployed and as production is expanded. For emerging technologies, the best information available at the time of the analysis was utilized, and cost assumptions will continue to be updated for any future analysis. Below, discussion of each category of technologies (*e.g.*, engines, transmissions, electrification) summarizes comments on corresponding direct cost estimates, and reviews estimates the agencies have applied for today's analysis.

b) Indirect Costs

As discussed above, direct costs represent the cost associated with acquiring raw materials, fabricating parts, and assembling vehicles with the various technologies manufacturers are expected to use to meet future CAFE and CO_2 standards. They include materials, labor, and variable energy costs required to produce and assemble the vehicle. However, they do not include overhead costs required to develop and produce the vehicle, costs incurred by manufacturers or dealers to sell vehicles, or the profit manufacturers and dealers make from their investments. All of these items contribute to the price consumers ultimately pay for the vehicle. These components of retail prices are illustrated in Table VI-15Table VI-15 below.

Table VI-15 - Retail Price Components

DIRECT COSTS	
Manufacturing Cost	Cost of materials, labor, and variable energy needed for production
INDIRECT COSTS	
Production Overhead	
Warranty	Cost of providing product warranty
Research and Development	Cost of developing and engineering the product
Depreciation and amortization	Depreciation and amortization of manufacturing facilities and equipment
Maintenance, repair, operations	Cost of maintaining and operating manufacturing facilities and equipment
Corporate Overhead	
General and Administrative	Salaries of nonmanufacturing labor, operations of corporate offices, etc.
Retirement	Cost of pensions for nonmanufacturing labor
Health Care	Cost of health care for nonmanufacturing labor
Selling Costs	
Transportation	Cost of transporting manufactured goods
Marketing	Manufacturer costs of advertising manufactured goods
Dealer Costs	
Dealer selling expense	Dealer selling and advertising expense
Dealer profit	Net Income to dealers from sales of new vehicles

Net income	Net income to manufacturers from production and sales of new vehicles

In addition to direct manufacturing costs, the agencies estimated and considered indirect manufacturing costs. To estimate indirect costs, direct manufacturing costs are multiplied by a factor to represent the average price for fuel-saving technologies at retail.

In the Draft TAR and preceding CAFE and safety rulemaking analyses, NHTSA relied on a factor, referred to as the retail price equivalent (RPE), to account for indirect manufacturing costs. The RPE accounts for indirect costs like engineering, sales, and administrative support, as well as other overhead costs, business expenses, warranty costs, and return on capital considerations. In the Draft TAR (and subsequent Determination) as well as the 2012 rulemaking analysis, EPA applied an "Indirect Cost Multiplier" (ICM) approach that it first applied in the 2010 rulemaking regarding standards for MYs 2012-2016, which also accounted for indirect manufacturing costs, albeit in a different way than the RPE approach.

Some commenters recommended the agencies rely on the ICM approach for the current rulemaking, citing EPA's prior peer review and use of this approach.[537] Others supported the agencies' reliance on the RPE approach, citing the National Research Council's observations in 2015 that the ICM approach lacks an empirical basis.[538] The agencies have carefully considered these comments, and conclude that while the ICM approach has conceptual merit, ~~its application requires a range of specific estimates, and data to support such estimates is scant and, in some cases, nonexistent. The agencies have, therefore, applied~~ the RPE approach for this final rule, as in the NPRM analysis and other rulemaking analyses. The following sections discuss both approaches in detail to explain why the RPE approach was chosen for this final rule.

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(1) Retail Price Equivalent

Historically, the method most commonly used to estimate indirect costs of producing a motor vehicle has been the retail price equivalent (RPE). The RPE markup factor is based on an examination of historical financial data contained in 10-K reports filed by manufacturers with the Securities and Exchange Commission (SEC). It represents the ratio between the retail price of motor vehicles and the direct costs of all activities that manufacturers engage in, including the design, development, manufacturing, assembly, and sales of new vehicles, refreshed vehicle designs, and modifications to meet safety or fuel economy standards.

Figure VI-5

Figure VI-5 indicates that for more than three decades, the retail price of motor vehicles has been, on average, roughly 50 percent above the direct cost expenditures of manufacturers.

[537] *See, e.g.*, ICCT, NHTSA-2018-0067-11741, Attachment 3, at 1-83. *See also* CFA, NHTSA-2018-0067-12005, Attachment B, at 189.

[538] *See, e.g.*, Alliance, NHTSA-2018-0067-12073, at 143. *See also* National Research Council, "Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles," 2015, available at https://www.nap.edu/catalog/21744/cost-effectiveness-and-deployment-of-fuel-economy-technologies-for-lightduty-vehicles ("…the empirical basis for such multipliers is still lacking, and, since their application depends on expert judgment, it is not possible for to determine whether the Agencies' ICMs are accurate or not").

This ratio has been remarkably consistent, averaging roughly 1.5 with minor variations from year to year over this period. At no point has the RPE markup exceeded 1.6 or fallen below 1.4.[539] During this time frame, the average annual increase in real direct costs was 2.5 percent, and the average annual increase in real indirect costs was also 2.5 percent. Figure VI-5Figure VI-5 illustrates the historical relationship between retail prices and direct manufacturing costs.[540]

An RPE of 1.5 does not imply that manufacturers automatically mark up each vehicle by exactly 50 percent. Rather, it means that, over time, the competitive marketplace has resulted in pricing structures that average out to this relationship across the entire industry. Prices for any individual model may be marked up at a higher or lower rate depending on market demand. The consumer who buys a popular vehicle may, in effect, subsidize the installation of a new technology in a less marketable vehicle. But, on average, over time and across the vehicle fleet, the retail price paid by consumers has risen by about $1.50 for each dollar of direct costs incurred by manufacturers.

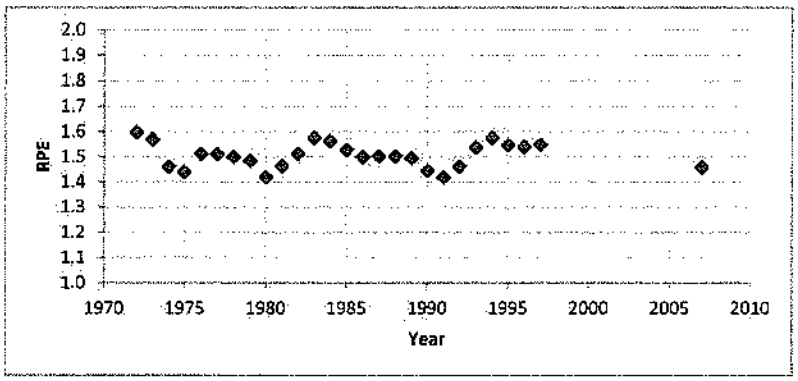


Figure VI-5 - Historical Data for Retail Price Equivalent (RPE), 1972-1997 and 2007

It is also important to note that direct costs associated with any specific technology will change over time as some combination of learning and resource price changes occurs. Resource costs, such as the price of steel, can fluctuate over time and can experience real long-term trends in either direction, depending on supply and demand. However, the normal learning process generally reduces direct production costs as manufacturers refine production techniques and seek out less costly parts and materials for increasing production volumes. By contrast, this learning process does not generally influence indirect costs. The implied RPE for any given technology

[539] Based on data from 1972-1997 and 2007. Data were not available for intervening years, but results for 2007 seem to indicate no significant change in the historical trend.

[540] Rogozhin, A., Gallaher, M., & McManus, W., 2009, Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers. Report by RTI International to Office of Transportation Air Quality. U.S. Environmental Protection Agency, RTI Project Number 0211577.002.004, February, Research Triangle Park, N.C.
Spinney, B.C., Faigin, B., Bowie, N., & St. Kratzke, 1999, Advanced Air Bag Systems Cost, Weight, and Lead Time analysis Summary Report, Contract NO. DTNH22-96-0-12003, Task Orders – 001, 003, and 005. Washington, D.C., U.S. Department of Transportation.

would thus be expected to grow over time as direct costs decline relative to indirect costs. The RPE for any given year is based on direct costs of technologies at different stages in their learning cycles, and which may have different implied RPEs than they did in previous years. The RPE averages 1.5 across the lifetime of technologies of all ages, with a lower average in earlier years of a technology's life, and, because of learning effects on direct costs, a higher average in later years.

Commented [A196]: **REVISE:** Evidence for this? Why aren't there learning opportunities in indirect costs? Is there evidence that indirect costs stay constant while tech costs decrease?

The RPE has been used in all NHTSA safety and most previous CAFE rulemakings to estimate costs. The National Academy of Sciences recommends RPEs of 1.5 for suppliers and 2.0 for in-house production be used to estimate total costs. The Alliance of Automobile Manufacturers also advocates these values as appropriate markup factors for estimating costs of technology changes. An RPE of 2.0 has also been adopted by a coalition of environmental and research groups (NESCCAF, ICCT, Southwest Research Institute, and TIAX-LLC) in a report on reducing heavy truck emissions, and 2.0 is recommended by the U.S. Department of Energy for estimating the cost of hybrid-electric and automotive fuel cell costs.

Table VI-16.

Table VI-16 below lists other estimates of the RPE. Note that all RPE estimates vary between 1.4 and 2.0, with most in the 1.4 to 1.7 range.

Table VI-16 - Alternate Estimates of the RPE[541]

Author and Year	Value, Comments
Jack Faucett Associates for EPA, 1985	1.26 initial value, later corrected to 1.7+ by Sierra research
Vyas et al, 2000	1.5 for outsourced, 2.0 for OEM, electric, and hybrid vehicles
NRC, 2002	1.4 (corrected to > by Duleep)
McKinsey and Company, 2003	1.7 based on European study
CARB, 2004	1.4 (derived using the JFA initial 1.26 value, not the corrected 1.7+ value)
Sierra Research for AAA, 2007	2.0 or >, based on Chrysler data
Duleep, 2008	1.4, 1.56, 1.7 based on integration complexity
NRC, 2010	1.5 for Tier 1 supplier, 2.0 for OEM

The RPE has thus enjoyed widespread use and acceptance by a variety of governmental, academic, and industry organizations. The RPE has been the most commonly used basis for indirect cost markups in regulatory analyses. However, as noted above, the RPE is an aggregate measure across all technologies applied by manufacturers and is not technology specific. A more detailed examination of these technologies is possible through an alternative measure, the indirect cost multiplier, which was developed to focus more specifically on technologies used to meet CAFE and CO_2 standards.

(2) Indirect Cost Multiplier

A second approach to accounting for indirect costs is the indirect cost multiplier (ICM). ICMs specifically evaluate the components of indirect costs likely to be affected by vehicle modifications associated with environmental regulation. EPA developed the ICM concept to enable the application of markups more specific to each technology. For example, the indirect cost implications of using tires with better rolling resistance would not be the same as those for developing an entire new hybrid vehicle technology, which would require far more R&D, capital investment, and management oversight. With more than 80 different technologies available to incrementally achieve fuel economy improvements,[542] a wide range of indirect cost effects might

[541] Duleep, K.G. "*2008 Analysis of Technology Cost and Retail Price*." Presentation to Committee on Assessment of Technologies for Improving Light Duty Vehicle Fuel Economy, January 25, Detroit, MI.; Jack Faucett Associates, September 4, 1985. Update of EPA's Motor Vehicle Emission Control Equipment Retail Price Equivalent (RPE) Calculation Formula. Chevy Chase, MD - Jack Faucett Associates; McKinsey & Company, October 2003. Preface to the Auto Sector Cases. *New Horizons - Multinational Company Investment in Developing Economies*, San Francisco, CA.; NRC (National Research Council), 2002. Effectiveness and Impact of Corporate Average Fuel Economy Standards, Washington, D.C. - The National Academies Press; NRC, 2011. Assessment of Fuel Economy Technologies for Light Duty Vehicles. Washington, D.C. - The National Academies Press; Sierra Research, Inc., November 21, 2007, Study of Industry-Average Mark-Up Factors used to Estimate Changes in Retail Price Equivalent (RPE) for Automotive Fuel Economy and Emissions Control Systems, Sacramento, CA - Sierra Research, Inc.; Vyas, A. Santini, D., & Cuenca, R. 2000. Comparison of Indirect Cost Multipliers for Vehicle Manufacturing. Center for Transportation Research, Argonne National Laboratory, April, Argonne, Ill.

[542] There are roughly 40 different basic unique technologies, but variations among these technologies roughly double the possible number of different technology applications.

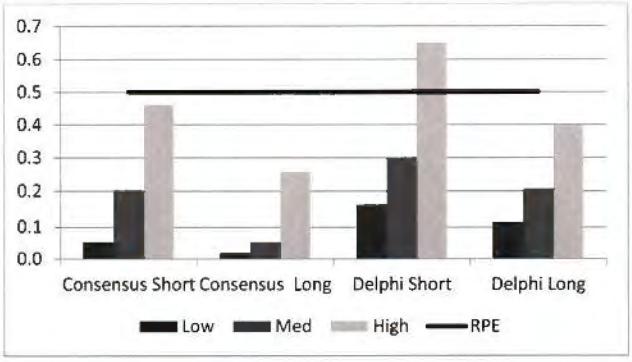
be expected. ICMs attempt to isolate only those indirect costs that would have to change to develop a specific technology. Thus, for example, if a company were to hire additional staff to sell vehicles equipped with fuel economy improving technology, or to search the technology requirements of new CO_2 or CAFE standards, the cost of these staff would be included in ICMs. ~~However, if these functions were accomplished by existing staff, they would not be included. For example, if an executive who normally devoted 10 percent of his time to fuel economy standards compliance were to devote 50 percent of his time in response to new more stringent requirements, his salary would not be included in ICMs because he would be paid the same salary regardless of whether he devoted his time to addressing CAFE requirements, developing new performance technologies, or improving the company's market share. ICMs thus do not account for the diverted resources required for manufacturers to meet these standards, but rather for the net change in costs manufacturers might experience because of hiring *additional* personal or acquiring *additional* assets or services.~~

Commented [A197]: DELETE: Factually incorrect.

For past rulemakings EPA developed both short-term and long-term ICMs. Long-term ICMs are lower than short-term ICMs. This decline reflects the belief that many indirect costs will decline over time. For example, research is initially required to develop a new technology and apply it throughout the vehicle fleet, but a lower level of research will be required to improve, maintain, or adapt that new technology to subsequent vehicle designs.

Commented [A198]: **REVISE**: Improvements and adaptations would not be done in response to the regulatory action being considered. Maintaining a technology does not sound like R&D. The opening sentence is fine – that sentence could be followed with an example that once R&D is done in response to the given regulatory action, it is done in the context of that regulatory action.

~~While the RPE was derived from data in financial statements (reflecting real-world operating and financial results), no similar data sources were available to estimate ICMs. ICMs are based on the RPE, broken into its components, as shown in Table VI-18 . Adjustment factors were then developed for those components, based on the complexity and time frame of low-, medium-, and high complexity technologies. The adjustment factors were developed from two panels of engineers with background in the automobile industry. Initially, a group of engineers met and developed an estimate of ICMs for three different technologies. This "consensus" panel examined one low complexity technology, one medium complexity technology, and one high complexity technology, with the initial intent of using these technologies to represent ICM factors for all technologies falling in those categories. At a later date, a second panel was convened to examine three more technologies (one low, one medium, and one high complexity), using a modified Delphi approach to estimate indirect cost effects. The results from the second panel identified the same pattern as those of the original report – the indirect cost multipliers increase with the complexity of the technology and decrease over time. The values derived in process are higher than those in the RPE/IC Report by values ranging from 0.09 (that is, the multiplier increased from 1.20 to 1.29) to 0.19 (the multiplier increased from 1.45 to 1.64). This variation may be due to differences in the technologies used in each panel. The results are shown in Figure VI-7, together with the historical average RPE.~~



~~Figure VI-7 – Indirect Cost Estimates from EPA Consensus and Delphi Panels, Short and Long Term~~

~~In subsequent CAFE and CO_2 analyses for MYs 2011, as well as for the 2012-2016 rulemaking, a simple average of the two resulting ICMs in the low and medium technology complexity categories was applied to direct costs for all unexamined technologies in each specific category. For high complexity technologies, the lower consensus-based estimate was used for high complexity technologies currently being produced, while the higher modified Delphi-based estimate was used for more advanced technologies, such as plug-in hybrid or electric vehicles, which had little or no current market penetration. Note that ICMs originally did not include profit or "return on capital," a fundamental difference from the RPE. However, prior to the 2012-2016 CAFE analysis, ICMs were modified to include provision for return on capital.~~

~~*(3) Application of ICMs in the 2017-2025 Analysis*~~

~~For the model year 2017-2025 rulemaking analysis, NHTSA and EPA revisited technologies evaluated by EPA staff and reconsidered their method of application. The agencies were concerned that averaging consensus and modified Delphi ICMs might not be the most accurate way to develop an estimate for the larger group of unexamined technologies. Specifically, there was concern that some technologies might not be representative of the larger groups they were chosen to represent. Further, the agencies were concerned that the values developed under the consensus method were not subject to the same analytical discipline as those developed from the modified Delphi method. As a result, the agencies relied primarily on the modified Delphi-based technologies to establish their revised distributions. Thus, for the MY 2017-2025 analysis, the agencies used the following basis for estimating ICMs:~~

- ~~All low complexity technologies were estimated to equal the ICM of the modified Delphi-based low technology-passive aerodynamic improvements.~~
- ~~All medium complexity technologies were estimated to equal the ICM of the modified Delphi-based medium technology-engine turbo-downsizing.~~

- ~~Strong hybrids and non-battery plug-in hybrid electric vehicles (PHEVs) were estimated to equal the ICM of the high complexity consensus-based high technology hybrid electric vehicle.~~
- ~~PHEVs with battery packs and full electric vehicles were estimated to equal the ICM of the high complexity modified Delphi-based high technology plug-in hybrid electric vehicle.~~

~~In addition to shifting the proxy basis for each technology group, the agencies reexamined each technology's complexity designation in light of the examined technologies that would serve as the basis for each group. The resulting designations together with the associated proxy technologies are shown in Table VI-18.~~

~~Table VI-18 Technology Designations by ICM Category, with Proxy Technology~~

~~Low Technology~~	~~Medium Technology~~	~~High Tech 1~~	~~High Tech 2~~
~~Passive Aerodynamic Improvements~~	~~Engine Turbo Downsizing~~	~~Hybrid Electric Vehicle~~	~~Plug-in Hybrid Electric Vehicle~~
~~Passive Aerodynamic Improv.~~	~~6-speed DCTs~~	~~Strong Hybrids~~	~~PHEV battery packs~~
~~Lubricant improvements~~	~~Mass Reduction 15-20%~~	~~PHEV and EV chargers~~	~~All Electric vehicles~~
~~Mass Reductions 3-10%~~	~~Turbocharging~~	~~PHEVs w/o batteries~~	
~~Aggressive Shift Logic~~	~~Cylinder deactivation~~		
~~Engine Friction Reduction~~	~~Dual valve timing and discreet lift~~		
~~Engine Downsizing~~	~~8-speed transmissions~~		
~~6 speed transmissions~~	~~12 volt start-stop systems~~		
~~Low Drag Brakes~~	~~Active aerodynamics~~		
~~Electro-hydraulic power steering~~	~~Diverting OHV/SOHC to DOHC~~		
~~Electronic power steering~~	~~Gasoline direct injection~~		
~~WT intake or coupled~~	~~Turbo downsizing~~		
~~Improved accessories~~	~~Turbo downsizing +EGR~~		
~~Early torque converter lockup~~	~~Diesel vehicles~~		
	~~Variable valve lift and timing~~		
	~~Lean-burn gasoline engines~~		

~~Many basic technologies noted in Table VI-19 have variations sharing the same complexity designation and ICM estimate. Table VI-19 lists each technology used in the CAFE model together with their ICM category and the year through which the short-term ICM would be applied. Note that the number behind each ICM category designation refers to the source of the ICM estimate, with 1 indicating the consensus panel and 2 indicating the modified Delphi panel.~~

~~Table VI-19 - ICM categories and Short-Term ICM Schedules for CAFE Technologies~~

~~Technology~~	~~ICM Category~~	~~Short Term Through~~
~~Low Friction Lubricants - Level 1~~	~~Low2~~	~~2018~~
~~Engine Friction Reduction - Level 1~~	~~Low2~~	~~2018~~
~~Low Friction Lubricants and Engine Friction Reduction - Level 2~~	~~Low2~~	~~2024~~
~~Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC~~	~~Low2~~	~~2018~~
~~Discrete Variable Valve Lift (DVVL) on SOHC~~	~~Medium2~~	~~2018~~
~~Cylinder Deactivation on SOHC~~	~~Medium2~~	~~2018~~
~~Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)~~	~~Low2~~	~~2018~~
~~Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)~~	~~Medium2~~	~~2018~~
~~Discrete Variable Valve Lift (DVVL) on DOHC~~	~~Medium2~~	~~2018~~
~~Continuously Variable Valve Lift (CVVL)~~	~~Medium2~~	~~2018~~
~~Cylinder Deactivation on DOHC~~	~~Medium2~~	~~2018~~
~~Stoichiometric Gasoline Direct Injection (GDI)~~	~~Medium2~~	~~2018~~
~~Cylinder Deactivation on OHV~~	~~Medium2~~	~~2018~~
~~Variable Valve Actuation - CCP and DVVL on OHV~~	~~Medium2~~	~~2018~~
~~Stoichiometric Gasoline Direct Injection (GDI) on OHV~~	~~Medium2~~	~~2018~~
~~Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement - Turbo~~	~~Medium2~~	~~2018~~
~~Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement - Turbo~~	~~Medium2~~	~~2018~~
~~Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement - Turbo~~	~~Medium2~~	~~2018~~
~~Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement - Turbo~~	~~Medium2~~	~~2024~~
~~Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement - Turbo~~	~~Medium2~~	~~2024~~

~~Technology~~	~~ICM Category~~	~~Short Term Through~~
~~Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement - Turbo~~	~~Medium2~~	~~2024~~
~~Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement - Turbo~~	~~Medium2~~	~~2024~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement - Turbo~~	~~Medium2~~	~~2024~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement - Turbo~~	~~Medium2~~	~~2024~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement - Turbo~~	~~Medium2~~	~~2024~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement - Turbo~~	~~Medium2~~	~~2024~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement - Turbo~~	~~Medium2~~	~~2024~~
~~Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement - Downsize~~	~~Medium2~~	~~2018~~
~~Advanced Diesel - Small Displacement~~	~~Medium2~~	~~2024~~
~~Advanced Diesel - Medium Displacement~~	~~Medium2~~	~~2024~~
~~Advanced Diesel - Large Displacement~~	~~Medium2~~	~~2024~~
~~6-Speed Manual/Improved Internals~~	~~Low2~~	~~2018~~
~~Improved Auto. Trans. Controls/Externals~~	~~Low2~~	~~2018~~
~~6-Speed Trans with Improved Internals (Auto)~~	~~Low2~~	~~2018~~
~~6-speed DCT~~	~~Medium2~~	~~2018~~
~~8-Speed Trans (Auto or DCT)~~	~~Medium2~~	~~2018~~
~~High Efficiency Gearbox w/ dry sump (Auto or DCT)~~	~~Low2~~	~~2024~~
~~Shift Optimizer~~	~~Low2~~	~~2024~~
~~Electric Power Steering~~	~~Low2~~	~~2018~~

~~Technology~~	~~ICM Category~~	~~Short Term Through~~
~~Improved Accessories - Level 1~~	~~Low2~~	~~2018~~
~~Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)~~	~~Low2~~	~~2024~~
~~12V Micro Hybrid (Stop-Start)~~	~~Medium2~~	~~2018~~
~~Integrated Starter Generator~~	~~High1~~	~~2018~~
~~Strong Hybrid (Powersplit or 2-Mode) - Level 1 - Battery~~	~~High1~~	~~2024~~
~~Strong Hybrid (Powersplit or 2-Mode) - Level 1 - Non-Battery~~	~~High1~~	~~2018~~
~~Conversion from SHEV1 to SHEV2~~	~~HIgh1~~	~~2018~~
~~Strong Hybrid (P2 Parallel or 2-Mode) - Level 2 - Battery~~	~~High1~~	~~2024~~
~~Strong Hybrid (P2 Parallel or 2-Mode) - Level 2 - Non-Battery~~	~~High1~~	~~2018~~
~~Plug-in Hybrid - 20 mi range - Battery~~	~~High2~~	~~2024~~
~~Plug-in Hybrid - 20 mi range - Non-Battery~~	~~High1~~	~~2018~~
~~Plug-in Hybrid - 40 mi range - Battery~~	~~High2~~	~~2024~~
~~Plug-in Hybrid - 40 mi range - Non-Battery~~	~~High1~~	~~2018~~
~~Electric Vehicle (Early Adopter) - 75-mile range - Battery~~	~~High2~~	~~2024~~
~~Electric Vehicle (Early Adopter) - 75-mile range - Non-Battery~~	~~High2~~	~~2024~~
~~Electric Vehicle (Early Adopter) - 100-mile range - Battery~~	~~High2~~	~~2024~~
~~Electric Vehicle (Early Adopter) - 100-mile range - Non-Battery~~	~~High2~~	~~2024~~
~~Electric Vehicle (Early Adopter) - 150-mile range - Battery~~	~~High2~~	~~2024~~
~~Electric Vehicle (Early Adopter) - 150-mile range - Non-Battery~~	~~High2~~	~~2024~~
~~Electric Vehicle (Broad Market) - 150-mile range - Battery~~	~~High2~~	~~2024~~
~~Electric Vehicle (Broad Market) - 150-mile range - Non-Battery~~	~~High2~~	~~2024~~
~~Fuel Cell Vehicle~~	~~High2~~	~~2024~~
~~Charger-PHEV20~~	~~High1~~	~~2024~~
~~Charger-PHEV40~~	~~High1~~	~~2024~~
~~Charger-EV~~	~~High1~~	~~2024~~
~~Charger-Labor~~	~~None~~	~~2024~~
~~Mass Reduction - Level 1~~	~~Low2~~	~~2018~~
~~Mass Reduction - Level 2~~	~~Low2~~	~~2018~~
~~Mass Reduction - Level 3~~	~~Low2~~	~~2018~~
~~Mass Reduction - Level 4~~	~~Low2~~	~~2018~~
~~Mass Reduction - Level 5~~	~~Low2~~	~~2018~~
~~Low Rolling Resistance Tires - Level 1~~	~~Low2~~	~~2018~~
~~Low Rolling Resistance Tires - Level 2~~	~~Low2~~	~~2024~~
~~Low Rolling Resistance Tires - Level 3~~	~~Low2~~	~~2024~~
~~Low Drag Brakes~~	~~Low2~~	~~2018~~
~~Secondary Axle Disconnect~~	~~Low2~~	~~2018~~
~~Aero Drag Reduction, Level 1~~	~~Low2~~	~~2018~~
~~Aero Drag Reduction, Level 2~~	~~Medium2~~	~~2024~~

~~An additional adjustment was made to ICMs to account for the fact that they were derived from the RPE analysis for a specific year (2007). The agencies believed it would be more appropriate to base ICMs on the expected long-term average RPE rather than that of one specific year. To account for this, ICMs were normalized to an average RPE multiplier level of 1.5.~~

~~Table VI-20 lists values of ICMs by technology category used in the previous MY 2017-2025 rulemaking. As noted previously, the Low 1 and Medium 1 categories, which were derived using the initial consensus panel, are not used. Short-term values applied to CAFE technologies thus range from 1.24 for Low complexity technologies, 1.39 for Medium complexity technologies, 1.56 for High1 complexity technologies, and 1.77 for High2 complexity technologies. When long-term ICMs are applied in the year following that noted in the far right column of Table VI-20, these values will drop to 1.19 for Low, 1.29 for Medium, 1.35 for High1 and 1.50 for High2 complexity technologies.~~

~~Table VI-20 – ICMs by Technology Category Previously Used in 2017-2025 CAFE Rule~~

	~~ICM Warranty~~		~~ICM Other Indirect Costs~~		~~ICM Ratio – All Costs~~	
~~ICMs2017+~~	~~Short Term~~	~~Long Term~~	~~Short Term~~	~~Long Term~~	~~Short Term~~	~~Long Term~~
~~Low1~~	~~0.0384~~	~~0.0197~~	~~0.0833~~	~~0.0658~~	~~1.1217~~	~~1.0855~~
~~Low2~~	~~0.0116~~	~~0.0054~~	~~0.2303~~	~~0.1871~~	~~1.2419~~	~~1.1925~~
~~Medium1~~	~~0.0515~~	~~0.0252~~	~~0.2303~~	~~0.0910~~	~~1.2818~~	~~1.1162~~
~~Medium2~~	~~0.0446~~	~~0.0310~~	~~0.3427~~	~~0.2587~~	~~1.3872~~	~~1.2897~~
~~High1~~	~~0.0647~~	~~0.0318~~	~~0.4989~~	~~0.3136~~	~~1.5636~~	~~1.3454~~
~~High2~~	~~0.0736~~	~~0.0488~~	~~0.6964~~	~~0.4478~~	~~1.7700~~	~~1.4966~~

~~Note that ICMs for warranty costs are listed separately in Table VI-21. This was done because warranty costs are treated differently than other indirect costs. In some previous analyses (prior to MY 2017-2025), learning was applied directly to total costs. However, the agencies believe learning curves are more appropriately applied only to direct costs, with indirect costs established up front based on the ICM and held constant while direct costs are reduced by learning. Warranties are an exception to this because warranty costs involve future replacement of defective parts, and the cost of these parts would reflect the effect of learning. Warranty costs were thus treated as being subject to learning along with direct costs.[543]~~

Commented [A199]: DELETE: This lengthy discussion of ICMs is unnecessary given that ICMs are not being used.

~~The effect of learning on direct costs, together with the eventual substitution of lower long-term ICMs, causes the effective markup from ICMs to differ from the initial ICM on a yearly basis. An example of how this occurs is provided in Table VI-21.[544] This table, which was originally developed for the MY 2017-2025 analysis, traces the effect of learning on direct~~

~~[543] Note that warranty costs also involve labor costs for installation. This is typically done at dealerships, and it is unlikely labor costs would be subject to learning curves that affect motor vehicle parts or assembly costs. However, the portion of these costs that is due to labor versus that due to parts is unknown, so for this analysis, learning is applied to the full warranty cost.~~

~~[544] Table VI-21/22 illustrates the learning process from the base year consistent with the direct cost estimate obtained by the agencies – it is a mature technology well into the flat portion of the learning curve. Note that costs were actually applied to this rulemaking example beginning with MY 2017.~~

~~costs and its implications for both total costs and the ICM-based markup. Direct costs are assigned a value (proportion) of 1 to facilitate analysis on the same basis as ICMs (in an ICM markup factor, the proportion of direct costs is represented by 1 while the proportion of indirect costs is represented by the fraction of 1 to the right of the decimal.) Table VI-21 examines the effects of these factors on turbocharged downsized engines, one of the more prevalent CAFE technologies.~~

~~Table VI-21 – Derived Annual ICMs for Turbocharged Downsized Engines~~

~~Year~~	~~Learning #11~~	~~Direct Costs~~	~~Other Indirect~~	~~Warranty~~	~~Total Costs~~	~~Effective ICM-based Markup~~
~~2010~~	~~0.03~~					
~~2011~~	~~0.03~~					
~~2012~~	~~0.03~~	~~1~~	~~0.3427~~	~~0.0446~~	~~1.3872~~	~~1.387~~
~~2013~~	~~0.03~~	~~0.97~~	~~0.3427~~	~~0.0432451~~	~~1.3559~~	~~1.398~~
~~2014~~	~~0.03~~	~~0.9409~~	~~0.3427~~	~~0.0419478~~	~~1.3255~~	~~1.409~~
~~2015~~	~~0.03~~	~~0.912673~~	~~0.3427~~	~~0.0406893~~	~~1.2960~~	~~1.420~~
~~2016~~	~~0.03~~	~~0.8852928~~	~~0.3427~~	~~0.0394687~~	~~1.2674~~	~~1.432~~
~~2017~~	~~0.02~~	~~0.867587~~	~~0.3427~~	~~0.0386793~~	~~1.2489~~	~~1.440~~
~~2018~~	~~0.02~~	~~0.8502352~~	~~0.3427~~	~~0.0379057~~	~~1.2308~~	~~1.448~~
~~2019~~	~~0.02~~	~~0.8332305~~	~~0.2587~~	~~0.0310~~	~~1.1229~~	~~1.348~~
~~2020~~	~~0.02~~	~~0.8165659~~	~~0.2587~~	~~0.0303882~~	~~1.1056~~	~~1.354~~
~~2021~~	~~0.02~~	~~0.8002346~~	~~0.2587~~	~~0.0297805~~	~~1.0887~~	~~1.360~~
~~2022~~	~~0.02~~	~~0.7842299~~	~~0.2587~~	~~0.0291849~~	~~1.0721~~	~~1.367~~
~~2023~~	~~0.02~~	~~0.7685453~~	~~0.2587~~	~~0.0286012~~	~~1.0558~~	~~1.374~~
~~2024~~	~~0.02~~	~~0.7531744~~	~~0.2587~~	~~0.0280291~~	~~1.0399~~	~~1.381~~
~~2025~~	~~0.02~~	~~0.7381109~~	~~0.2587~~	~~0.0274686~~	~~1.0243~~	~~1.388~~
~~2026~~	~~0.01~~	~~0.7307298~~	~~0.2587~~	~~0.0271939~~	~~1.0166~~	~~1.391~~
~~2027~~	~~0.01~~	~~0.7234225~~	~~0.2587~~	~~0.0269219~~	~~1.0090~~	~~1.395~~
~~2028~~	~~0.01~~	~~0.7161883~~	~~0.2587~~	~~0.0266527~~	~~1.0015~~	~~1.398~~
~~2029~~	~~0.01~~	~~0.7090264~~	~~0.2587~~	~~0.0263862~~	~~0.9941~~	~~1.402~~
~~2030~~	~~0.01~~	~~0.7019361~~	~~0.2587~~	~~0.0261223~~	~~0.9867~~	~~1.406~~
~~Average ICM-based markup 2017 through 2030~~						~~1.389~~

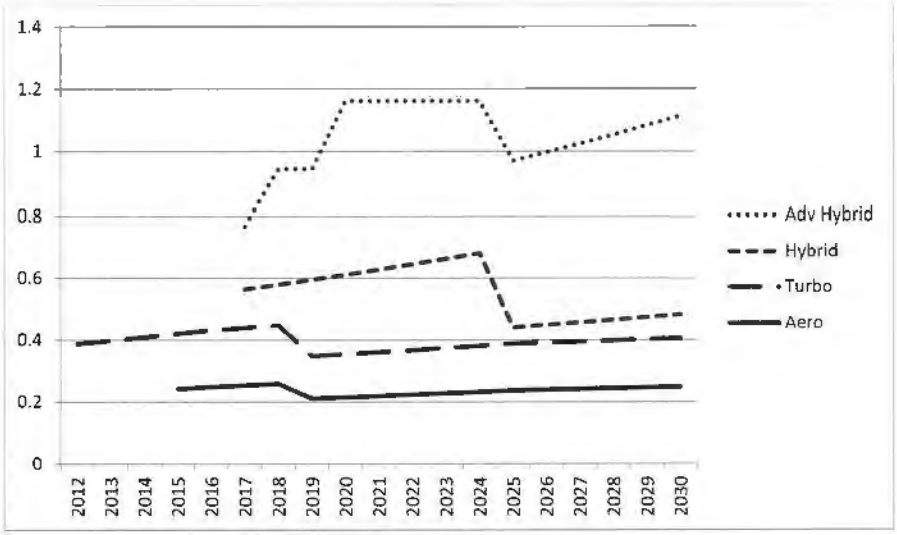
~~The second column of Table VI-22 lists the learning schedule applied to turbocharged downsized engines. Turbocharged downsized engines are a mature technology, so the learning schedule captures the relatively flat portion of the learning curve occurring after larger decreases have already reduced direct costs. The cost basis for turbocharged downsized engines in the analysis was effective in 2012, so this is the base year for this calculation when direct costs are set to 1. The third column shows the progressive decline in direct costs as the learning schedule in column 2 is applied to direct costs. Column 4 contains the value of all indirect costs except warranty. Turbocharged downsized engines are a medium-complexity technology, so this value is taken from the Medium2 row of Table VI-21. The initial value in 2012 is the short-term value, which is used through 2018. During this time, these indirect costs are not affected by~~

~~learning, and they remain constant. Beginning in 2019, the long-term ICM from Table VI-21 is applied.~~

~~The fifth column contains warranty costs. As previously mentioned, these costs are considered to be affected by learning like direct costs, so they decline steadily until the long-term ICM is applied in 2019, at which point they drop noticeably before continuing their gradual decline. In the sixth column, direct and indirect costs are totaled. Results indicate a decline in total costs of roughly 30 percent during this 14-year period. The last column shows the effective ICM-based markup, which is derived by dividing total costs by direct costs. Over this period, the ICM-based markup rose from the initial short-term ICM level of 1.39 to 1.45 in 2018. It then declined to 1.35 in 2019 when the long-term ICM was applied to the 2019 direct cost. Over the remaining years, it gradually rises back up to 1.41 as learning continues to degrade direct costs.~~

~~There are thus two somewhat offsetting processes affecting total costs derived from ICMs. The first is the learning curve, which reduces direct costs, which raises the effective ICM-based markup. As noted previously, learning reflects learned efficiencies in assembly methods as well as reduced parts and materials costs. The second is the application of a long-term ICM, which reduces the effective ICM-based markup. This represents the reduced burden needed to maintain new technologies once they are fully developed. In this case, the two processes largely offset one another and produce an average real ICM over this 14-year period that roughly equals the original short-term ICM.~~

~~Figure VI-8 illustrates this process for each of the 4 technologies used to represent the universe of fuel-economy and CO_2-improving technologies. As with the turbocharged engines, aerodynamic improvements and mild hybrid vehicles show a gradual increase in the effective ICM-based markup through the point where the long-term ICM is applied. At that time, the ICM-based markup makes an abrupt decline before beginning a gradual rise. The decline due to application of long-term ICMs is particularly pronounced in the case of the mild hybrid—even more so than for the advanced hybrid. The advanced hybrid ICM behaves somewhat differently because it is shown through its developing stages when more radical learning is applied, but only every few years. This produces a significant step-up in ICM levels concurrent with each learning application, followed by a sharp decline when the long-term ICM is applied. After that, it begins a gradual rise as more moderate learning is applied to reflect its shift to a mature technology. Note that as with the turbocharged downsized engine example above, for the aerodynamic improvements and mild hybrid technologies, the offsetting processes of learning and long-term ICMs result in an average ICM over the full time frame that is roughly equal to the initial short-term ICM. However, the advanced hybrid ICM rose to a level significantly higher than the initial ICM. This is a direct function of the rapid learning schedule applied in the early years to this developing technology. Brand new technologies might thus be expected to have effective lifetime ICM markups exceeding their initial ICMs, while more mature technologies are more likely to experience ICMs over their remaining life span that more closely approximate their initial ICMs.~~



~~Figure VI-8 – Derived ICM-Based Markups for Advanced Hybrids, Weak Hybrids, Turbo Downsized Engines, and Passive Aerodynamic Improvements~~

~~ICMs for these 4 technologies would drive the indirect cost markup rate for the analysis. However, the effect on total costs is also a function of the relative incidence of each of the 50+ technologies shown in Table VI-20 which are assumed to have ICMs similar to one of these 4 technologies. The net effect on costs of these ICMs is also influenced by the learning curve appropriate to each technology, creating numerous different and unique ICM paths. The average ICM applied by the model is also a function of each technology's direct cost and because ICMs are applied to direct costs, the measured indirect cost is proportionately higher for any given ICM when direct costs are higher. The average ICM applied to the fleet for any given model year is calculated as follows:~~

~~Equation VI-1 – Average ICM Calculation~~

$$\sum_{1}^{88} \frac{D_n A_n}{\sum_1^{88} D_n A_n} * ICM_n$$

~~where—~~

~~D = direct cost of each technology~~
~~A = application rate for each technology~~
~~ICM = average ICM applied to each technology~~
~~and n=1,2,…88~~

~~The CAFE model predicts technology application rates assuming manufacturers will apply technologies to meet standards in a logical fashion based on estimated costs and benefits. The application rates will thus be different for each model year and for each alternative scenario examined. For the MY 2017-2025 FRIA, to illustrate the effects of ICMs on total technology costs, NHTSA calculated the weighted average ICM across all technologies for the preferred alternative.[545] This was done separately for each vehicle type and then aggregated based on predicted sales of each vehicle type used in the model. Results are shown in Table VI-22.~~

~~Table VI-22 – Average ICM-Based Markups Applied in Preferred Alternative Scenario MY 2017-2025 FRIA~~

~~Model Year~~	~~Passenger Cars~~	~~Light Trucks~~	~~All Vehicles~~
~~2017~~	~~0.393~~	~~0.370~~	~~0.383~~
~~2018~~	~~0.40~~	~~0.377~~	~~0.390~~
~~2019~~	~~0.315~~	~~0.308~~	~~0.312~~
~~2020~~	~~0.322~~	~~0.317~~	~~0.320~~
~~2021~~	~~0.330~~	~~0.323~~	~~0.327~~
~~2022~~	~~0.336~~	~~0.329~~	~~0.333~~
~~2023~~	~~0.344~~	~~0.337~~	~~0.341~~
~~2024~~	~~0.357~~	~~0.343~~	~~0.351~~
~~2025~~	~~0.340~~	~~0.319~~	~~0.331~~
~~All Years~~	~~0.348~~	~~0.336~~	~~0.343~~

~~The ICM-based markups in Table VI-23 were derived in a manner consistent with the way the RPE is measured, that is, they reflect combined influences of direct cost learning and changes in indirect cost requirements weighted by both the incidence of each technology's adaptation and the relative direct cost of each technology. The results indicate generally higher ICMs for passenger cars than for light trucks. This is a function of the technologies estimated to be adopted for each respective vehicle type, especially in later years when hybrids and electric vehicles become more prevalent in the passenger car fleet. The influence of these advanced vehicles is driven primarily by their direct costs, which greatly outweigh the costs of other technologies. This results in the application of much more weight to their higher ICMs. This is most notable in MYs 2024 and 2025 for passenger cars, when electric vehicles begin to enter the fleet. The average ICM increased 0.013 in 2024 primarily because of these vehicles. It immediately dropped 0.017 in 2025 because both an additional application of steep (20 percent) learning is applied to the direct cost of these vehicles (which reduces their relative weight), and the long-term ICM becomes effective in that year (which decreases the absolute ICM factor). Both influences occur one year after these vehicles begin to enter the fleet because of CAFE requirements.~~

~~[545] For each alternative, this rulemaking examined numerous scenarios based on different assumptions, and these assumptions could influence the relative frequency of selection of different technologies, which in turn could affect the average ICM. The scenarios examined here assumed a 7-percent discount rate, a 1-year payback period, real world application of expected civil penalties, and reflects expected voluntary over-compliance by manufacturers.~~

~~ICMs also change over time, again, reflecting the different mix of technologies present during earlier years but that are often replaced with more expensive technologies in later years. Across all model years, the wide-ranging application of diverse technologies required to meet CAFE and CO_2 standards produced an average ICM-based markup (or RPE equivalent) of approximately 1.34, applying only 67 percent of the indirect costs found in the RPE and implying total costs 11 percent below those predicted by the RPE-based calculation.~~

~~(4)~~(3) *Uncertainty*

As noted above, the RPE and ICM assign different markups over direct manufacturing costs, and thus imply different total cost estimates for CAFE and CO_2 technologies. While there is a level of uncertainty associated with both markups, this uncertainty stems from different issues. The RPE is derived from financial statements and is thus grounded in historical data. Although compilation of this data is subject to some level of interpretation, the two independent researchers who derived RPE estimates from these financial reports each reached essentially identical conclusions, placing the RPE at roughly 1.5. All other estimates of the RPE fall between 1.4 and 2.0, and most are between 1.4 and 1.7. There is thus a reasonable level of consistency among researchers that RPEs are 1.4 or greater. In addition, the RPE is a measure of the cumulative effects of all operations manufacturers undertake in the course of producing their vehicles, and is thus not specific to individual technologies, nor of CAFE or CO_2 technologies in particular. Because this provides only a single aggregate measure, using the RPE multiplier results in the application of a common incremental markup to all technologies. This assures the aggregate cost effect across all technologies is consistent with empirical data, but it does not allow for indirect cost discrimination among different technologies or over time. Because it is applied across all changes, this implies the markup for some technologies is likely to be understated, and for others it is likely to be overstated.

By contrast, the ICM process derives markups specific to several CAFE and CO_2 technologies~~, but these markups have no basis in empirical data~~. They are based on informed judgment of a panel of engineers with auto industry experience regarding cost effects of a small sample (roughly 8 percent) of the 50+ technologies applied to achieve compliance with CAFE and CO_2 standards. Uncertainty regarding ICMs is thus based both on the accuracy of the initial assessments of the panel on the examined technologies and on the assumption that these 4 technologies are representative of the remaining technologies that were not examined. Both agencies attempted to categorize these technologies in the most representative way possible. However, while this represented the best judgment of EPA and NHTSA's engineering staffs at that time, the actual effect on indirect costs remains uncertain for most technologies. As with RPEs, this means that even if ICMs were accurate for the specific technologies examined, indirect cost will be understated for some technologies and overstated for others.

~~There was considerable uncertainty demonstrated in the ICM panel's assessments, as illustrated by the range of estimates among the 11 modified Delphi panel members surrounding the central values reported by the panel. These ranges are shown in Table VI-23 and Figure VI-9, Figure VI-10, and Figure VI-11 below. For the low complexity technology, passive aerodynamic improvements, panel responses ranged from a low of basically no indirect costs (1.001 short term and 1.0 long term), to a high of roughly a 40 percent markup (1.134 and~~

Commented [A200]: DELETE: None of this seems to speak to why RPEs are being used rather than ICMs. The level of detail almost strengthens the ICM approach as appearing more comprehensive and the focus on ICM gives the impression of trying to convince the reader of why ICMs, the newer approach, is better.

Commented [A201]: DELETE: None of this seems to speak to why RPEs are being used rather than ICMs. The level of detail almost strengthens the ICM approach as appearing more comprehensive and the focus on ICM gives the impression of trying to convince the reader of why ICMs, the newer approach, is better. The ICM detail seems counter-productive from defensibility standpoint.

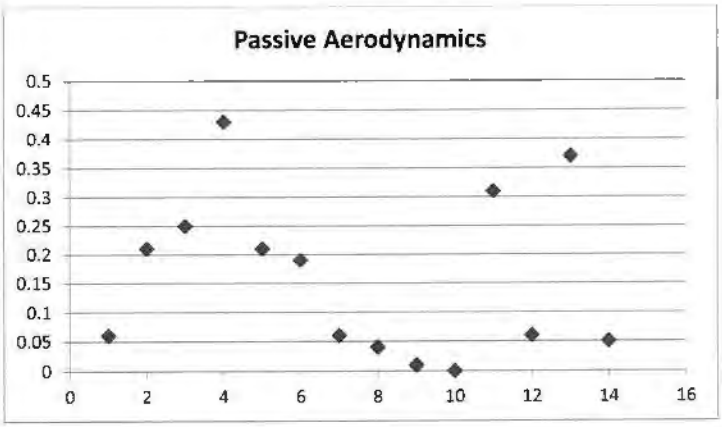
Commented [A202]: DELETE: Factually incorrect

Commented [A203]: DELETE: As with above comment, this whole section is irrelevant to the choice of using RPEs. There is plenty of documentation of the ICM approach used in past rules and MTE documents that could simply be cited as background to the ICMs.

~~1.421). For the medium complexity technology, turbo charged and downsized engines, responses ranged from a low estimate implying almost no indirect cost (1.018 and 1.011), to a high estimate implying that indirect costs for this technology would roughly equal the average RPE (1.5) for all technologies (1.527 and 1.445). For the high complexity technology, plug-in hybrid electric vehicles, responses ranged from a low estimate that these vehicles would require significantly less indirect cost than the average RPE (1.367 and 1.121) to a high estimate implying they would require more indirect costs than the average RPE (2.153 and 1.691). There was considerable diversity of opinion among the panel members.[546] This is apparent in Figure VI-9, Figure VI-10, and Figure VI-11, which show the 14 panel members' final estimates for short-term ICMs as scatter plots.~~

~~Table VI-23 – Indirect Cost Multipliers – Modified Delphi Panel~~

-	Short Run			Long Run		
-	Low	Medium	High	Low	Medium	High
Average	1.16	1.29	1.64	1.12	1.2	1.39
Median	1.24	1.264	1.659	1.062	1.199	1.396
Minimum	1.001	1.018	1.367	1	1.011	1.121
Maximum	1.434	1.527	2.153	1.424	1.445	1.691
Std Deviation	0.141	0.145	0.207	0.137	0.131	0.152
t-distribution – Low	1.079	1.206	1.521	1.041	1.124	1.302
t-distribution – High	1.241	1.374	1.759	1.199	1.276	1.478



~~[546] Sample confidence intervals, which mitigate the effect of outlying opinions, indicate a less extreme but still significant range of ICMs. Applying mean ICMs helps mitigate these potential differences, but there is clearly a significant level of uncertainty regarding indirect costs. A t-distribution is used to estimate confidence intervals because of the small sample size (14 panel members).~~

Figure VI-9 – Low Complexity ICM Panel Results

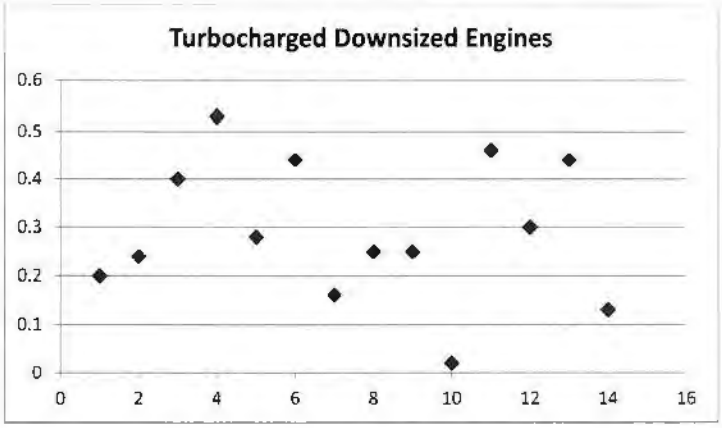


Figure VI-10 – Medium Complexity ICM Panel Results

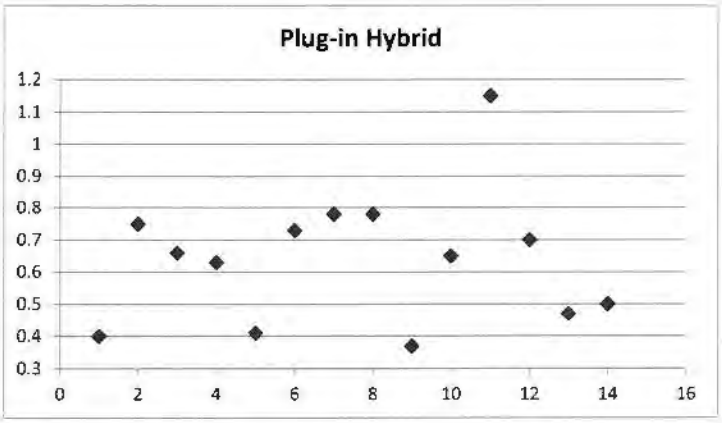


Figure VI-11 – High Complexity ICM Panel Results

Although these results were based on modified Delphi panel techniques, it is apparent the goal of the Delphi process, an eventual consensus or convergence of opinion among panel experts, was not achieved. Given this lack of consensus and the divergence of ICM-based results

~~from the only available empirical measure (the RPE), there is considerable uncertainty that current ICM estimates provide a realistic basis of estimating indirect costs. ICMs have not been validated through a direct accounting of actual indirect costs for individual technologies, and they produce results that conflict with the only available empirical evidence of indirect cost markups. Further, they are intended to represent indirect costs specifically associated with the most comprehensive redesign effort ever undertaken by the auto industry, with virtually every make/model requiring ground-up design modifications to comply. This includes entirely new vehicle design concepts, extensive material substitution, and complete drivetrain redesigns, all of which require significant research efforts and assembly plant redesign. Under these circumstances, one might expect indirect costs to equal or possibly increase above the historical average, but not to decrease, as implied by estimated ICMs. For regulations, such as the CAFE and CO_2 emission standards under consideration, that drive changes to nearly every vehicle system, the overall average indirect costs should align with the RPE value. Applying RPE to the cost for each technology assures that alignment.~~

In the 2015 NAS study, the Committee stated a conceptual agreement with the ICM method because ICM takes into account design challenges and the activities required to implement each technology. However, although endorsing ICMs as a concept, the NAS Committee stated "the empirical basis for such multipliers is still lacking, and, since their application depends on expert judgment, it is not possible to determine whether the Agencies' ICMs are accurate or not."[547] NAS also stated "the specific values for the ICMs are critical because they may affect the overall estimates of costs and benefits for the overall standards and the cost effectiveness of the individual technologies."[548] The Committee encouraged continued research into ICMs given the lack of empirical data for them to evaluate ICMs used by the agencies in past analyses. On balance, and considering the relative merits of both approaches for realistically estimating indirect costs, the agencies consider the RPE method to be a ~~more reliable~~reasonable and appropriate basis for estimating indirect costs.

~~(5)~~(4) *Using RPE to Evaluate Indirect Costs in this Analysis*

To ensure overall indirect costs in the analysis align with the historical RPE value, the primary analysis has been developed based on applying the RPE value of 1.5 to each technology. As noted previously, the RPE is the ratio of aggregate retail prices to aggregate direct manufacturing costs. The ratio already reflects the mixture of learned costs of technologies at various stages of maturity. Therefore, the RPE is applied directly to the learned direct cost for each technology in each year. This was previously done in the MY 2017-2025 FRIA for the preferred alternative for that rulemaking, used in the above analysis of average ICMs. Results are shown in Table VI-17Table VI-17.

Recognizing there is uncertainty in any estimate of indirect costs, a sensitivity analyses of indirect costs has also been conducted by applying a lower RPE value as a proxy for the ICM approach. This value was derived from a direct comparison of incremental technology costs

[547] National Research Council of the National Academies (2015). Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. https://www.nap.edu/resource/21744/deps_166210.pdf.
[548] *Ibid.*

determined in the MY 2017-2025 FRIA.[549] This analysis is summarized in Table VI-17Table VI-17 below. From this table, total costs were estimated to be roughly 18 percent lower using ICMs compared to the RPE. As previously mentioned, there are two different reasons for these differences. The first is the direct effect of applying a higher retail markup. The second is an indirect effect resulting from the influence these differing markups have on the order of the selection of technologies in the CAFE model, which can change as different direct cost levels interact with altered retail markups, shifting their relative overall effectiveness.

The relative effects of ICMs may vary somewhat by scenario, but in this case, the application of ICMs produces total technology cost estimates roughly 18 percent lower than those that would result from applying a single RPE factor to all technologies, or, conversely, the RPE produces estimates that averaged 21 percent higher than the ICM. Under the CAFE model construct, which will apply an alternate RPE to the same base technology profile to represent ICMs, this implies an RPE equivalent of 1.24 would produce similar net impacts [1.5/(1+x) = 1.21, x=0.24]. This value is applied for the ICM proxy estimate. Additional values were also examined over a range of 1.1-2.0. The results, as well as the reference case using the 1.5 RPE, are summarized in Table VI-18Table VI-18. [In each case, regardless of the RPE markup, Alternative 1 maximizes net benefits.]

Table VI-17 - Relative Impacts of Applying ICMs vs. RPE to Determine Indirect Costs

	Incremental Technology Total Costs (Millions$)		Ratios		Difference
Model Year	ICM	1.5 RPE	RPE/ICM	ICM/RPE	RPE-ICM
2017	$3,722	$3,749	1.01	0.99	0.01
2018	$5,227	$5,522	1.06	0.95	0.05
2019	$8,256	$9,604	1.16	0.86	0.14
2020	$10,809	$12,451	1.15	0.87	0.13
2021	$14,033	$16,214	1.16	0.87	0.13
2022	$15,262	$18,079	1.18	0.84	0.16
2023	$16,883	$20,806	1.23	0.81	0.19
2024	$19,727	$24,691	1.25	0.80	0.20
2025	$20,015	$27,244	1.36	0.73	0.27
Total	$113,935	$138,361	1.21	0.82	0.18

Table VI-18 - Net Benefits for Technology Cost Markup Sensitivity Runs Across Scenarios (through MY 2029) CAFE Program, 3% Discount Rate ($B)

	Alternative							
Sensitivity Case	1	2	3	4	5	6	7	8
Reference Case 1.50	176.3	168.1	155.1	143.2	120.0	95.9	40.8	60.5

[549] *See* Table 5-9a in Final Regulatory Impact Analysis, Corporate Average Fuel Economy for MY 2017-MY 2025 Passenger Cars and Light Trucks.

Technology Cost Markup 1.10	99.1	94.8	85.1	81.8	66.1	52.7	21.5	32.6
Technology Cost Markup 1.19	115.2	110.7	99.9	95.2	76.7	64.2	26.1	38.7
ICM Equivalent Markup 1.24	124.1	119.6	108.2	103.3	84.9	69.5	27.5	42.3
Technology Cost Markup 1.37	146.8	139.5	125.4	119.1	102.8	80.6	30.1	49.9
Technology Cost Markup 1.75	227.3	218.2	204.1	187.8	148.5	119.8	54.2	71.3
Technology Cost Markup 2.00	273.7	260.7	241.7	215.5	178.1	141.5	62.3	85.3

]

Several responders submitted comments on the issue of indirect costs. The International Council on Clean Transportation (ICCT) stated that "The agencies abandoned their previously-used indirect cost multiplier method for estimating total costs, which was vetted with peer review, and more complexly handled differing technologies with different supply chain and manufacturing aspects. The agencies have, at this point, opted to use a simplistic retail price equivalent method, which crudely assumes all technologies have a 50 percent markup from the direct manufacturing technology cost. We recommend the agencies revert back to the previously-used and better substantiated ICM approach."[550]

A private commenter, Thomas Stephens, noted that "In Section II. Technical Foundation for NPRM Analysis, under 1. Data Sources and Processes for Developing Individual Technology Assumptions, the agencies state that indirect costs are estimated using a Retail Price Equivalent (RPE) factor. Concerns with RPE factors and the difficulty of accounting for differences in indirect costs of different technologies when using this approach were identified by the EPA (Rogozhin et al., Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry, International Journal of Production Economics 124, 360-368, 2010), which suggested using indirect cost (IC) multipliers instead of RPE factors. The EPA developed and updated IC multipliers for relevant vehicle technologies with automotive industry input and review. The agencies should consider using these IC multipliers to estimate indirect manufacturing costs instead of RPE factors."[551]

By contrast, the Alliance of Automobile Manufacturers (The Alliance) supports the use of retail price equivalents in the compliance cost modeling to estimate the indirect costs associated with the additional added technology required to meet a given future standard. "The alternative indirect cost multiplier ("ICM") approach is not sufficiently developed for use in rulemaking. As noted by the National Research Council, the indirect cost multipliers previously developed by EPA have not been validated with empirical data.[552] Furthermore, in reference to the memorandum documenting the development of ICMs previously used by EPA, Exponent Failure Analysis Associates found that,

[550] NHTSA-2018-0067-11741.
[551] NHTSA-2018-0067-12067.
[552] Cost, Effectiveness, and Development of Fuel Economy Technologies for Light-Duty Vehicles, pages 248-49, National research Council, the National Academies Press (2015).

Large variations were observed between questionnaire responses found in an August 2009 memorandum (average coefficient of variations across all cost contributors was greater than 1, indicating potential disagreement between the experts on the relative impact of the different cost contributors), and review of the respondents' comments indicates confusion and lack of expertise in some areas. The discrepancies between questionnaire responses from the EPA experts, and these experts' potential lack of understanding of the different cost contributors, are not consistent with a rigorous and scientifically sound analysis."[553]

In response to these comments the agencies continue to find the RPE approach ~~preferable~~ is reasonable and appripriate~~to the ICM approach~~, at least at this stage in the development ICM estimates, for the reasons discussed both above and previously in the NPRM. ~~We note that our concerns are not with the concept of ICMs, but rather with the judgment-based values suggested for use as ICMs, which have not been validated, and which conflict with the empirically derived RPE value.~~ [TEXT Forthcoming] The agencies will continue to monitor any developments in ICM methodologies as part of future rulemakings.

c) Stranded Capital Costs

Past analyses accounted for costs associated with stranded capital when fuel economy standards caused a technology to be replaced before its costs were fully amortized. The idea behind stranded capital is that manufacturers amortize research, development, and tooling expenses over many years, especially for engines and transmissions. The traditional production life-cycles for transmissions and engines have been a decade or longer. If a manufacturer launches or updates a product with fuel-saving technology, and then later replaces that technology with an unrelated or different fuel-saving technology before the equipment and research and development investments have been fully paid off, there will be unrecouped, or stranded, capital costs. Quantifying stranded capital costs accounts for such lost investments.

In the Draft TAR and NPRM analyses, only a few technologies for a few manufacturers were projected to have stranded capital costs. As more technologies are included in this analysis, and as the CAFE model has been expanded to account for platform and engine sharing and updated with redesign and refresh cycles, accounting for stranded capital has become increasingly complex. Separately, manufacturers may be shifting their investment strategies in ways that may alter how stranded capital calculations were traditionally considered. For example, some suppliers sell similar transmissions to multiple manufacturers. Such arrangements allow manufacturers to share in capital expenditures, or amortize expenses more quickly.

Manufacturers share parts on vehicles around the globe, achieving greater scale and greatly affecting tooling strategies and costs. Given these trends in the industry and their uncertain effect on capital amortization, and given the difficulty of handling this uncertainty in the CAFE model, this analysis does not account for stranded capital. The agencies' analysis continues to rely on the CAFE model's explicit year-by-year accounting for estimated refresh

[553] NHTSA-2018-0067-12073.

and redesign cycles, and shared vehicle platforms and engines, to moderate the cadence of technology adoption and thereby limit the implied occurrence of stranded capital and the need to account for it explicitly. The agencies will monitor these trends to assess the role of stranded capital moving forward

d) Cost Learning

Manufacturers make improvements to production processes over time, which often result in lower costs. "Cost learning" reflects the effect of experience and volume on the cost of production, which generally results in better utilization of resources, leading to higher and more efficient production. As manufacturers gain experience through production, they refine production techniques, raw material and component sources, and assembly methods to maximize efficiency and reduce production costs. Typically, a representation of this cost learning, or learning curves, reflect initial learning rates that are relatively high, followed by slower learning as additional improvements are made and production efficiency peaks. This eventually produces an asymptotic shape to the learning curve, as small percent decreases are applied to gradually declining cost levels. These learning curve estimates are applied to various technologies that are used to meet CAFE standards.

For the NPRM and this final rule, the agencies estimated cost learning by considering methods established by T.P. Wright[554] and later expanded upon by J.R. Crawford. Wright, examining aircraft production, found that every doubling of cumulative production of airplanes resulted in decreasing labor hours at a fixed percentage. This fixed percentage is commonly referred to as the progress rate or progress ratio, where a lower rate implies faster learning as cumulative production increases. J.R. Crawford expanded upon Wright's learning curve theory to develop a single unit cost model,[555] that estimates the cost of the nth unit produced given the following information is known: (1) cost to produce the first unit; (2) cumulative production of n units; and (3) the progress ratio.

As pictured in Figure VI-6Figure VI-6, Wright's learning curve shows the first unit is produced at a cost of $1,000. Initially cost per unit falls rapidly for each successive unit produced. However, as production continues, cost falls more gradually at a decreasing rate. For each doubling of cumulative production at any level, cost per unit declines 20 percent, so that 80 percent of cost is retained. The CAFE model uses the basic approach by Wright, where cost reduction is estimated by applying a fixed percentage to the projected cumulative production of a given fuel economy technology.

[554] Wright, T. P., Factors Affecting the Cost of Airplanes. *Journal of Aeronautical Sciences*, Vol. 3 (1936), pp.124-125. Available at http://www.uvm.edu/pdodds/research/papers/others/1936/wright1936a.pdf.
[555] Crawford, J.R., *Learning Curve, Ship Curve, Ratios, Related Data*, Burbank, California-Lockheed Aircraft Corporation (1944).

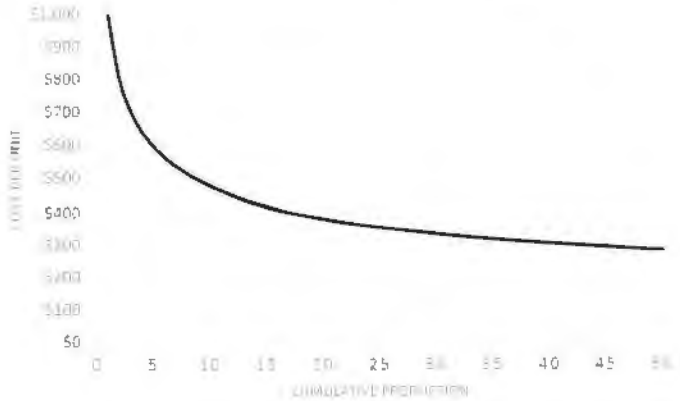


Figure VI-6 - Wright's Learning Curve (Progress Ratio = 0.8)

The analysis accounts for learning effects with model year-based cost learning forecasts for each technology that reduce direct manufacturing costs over time. The agencies evaluated the historical use of technologies, and reviewed industry forecasts to estimate future volumes for the purpose of developing the model year-based technology cost learning curves.

The following section discusses the agencies' development of model year-based cost learning forecasts, including how the approach has evolved from the 2012 rulemaking for MY 2017-2025 vehicles, and how the progress ratios were developed for different technologies considered in the analysis. Finally, the agencies discuss how these learning effects are applied in the CAFE Model.

(1) Time versus Volume-Based Learning

Commented [A204]: REVISE: EPA's studies of learning have gone to considerable lengths to clarify that what we once termed "time-based" learning was actually learning occuring on the flatter portion of the traditional learning curve and that "volume" based learning was learning on the steep portion of the curve. We suggest using those distinctions rather than time/volume.

For the 2012 joint CAFE/CO_2 rulemaking, the agencies developed learning curves as a function of vehicle model year.[556] Although the concept of this methodology is derived from Wright's cumulative production volume-based learning curve, its application for CAFE and CO_2 technologies was more of a function of time. More than a dozen learning curve schedules were developed, varying between fast and slow learning, and assigned to each technology corresponding to its level of complexity and maturity. The schedules were applied to the base year of direct manufacturing cost and incorporate a percentage of cost reduction by model year declining at a decreasing rate through the technology's production life. Some newer technologies experience 20 percent cost reductions for introductory model years, while mature or less complex technologies experience 0-3 percent cost reductions over a few years.

In their 2015 report to Congress, the National Academy of Sciences (NAS) recommended the agencies should "continue to conduct and review empirical evidence for the cost reductions

[556] CAFE 2012 Final Rule, NHTSA DOT, 77 FR 62624.

that occur in the automobile industry with volume, especially for large-volume technologies that will be relied on to meet the CAFE [CO_2] standards."[557]

In response, the agencies have incorporated statically projected cumulative volume production data of fuel economy improving technologies, representing an improvement over the previously used time-based method. Dynamic projections of cumulative production are not feasible with current CAFE model capabilities, so one set of projected cumulative production data for most vehicle technologies was developed for the purpose of determining cost impact. For many technologies produced and/or sold in the U.S., historical cumulative production data was obtained to establish a starting point for learning schedules. Groups of similar technologies or technologies of similar complexity may share identical learning schedules.

The slope of the learning curve, which determines the rate at which cost reductions occur, has been estimated using research from an extensive literature review and automotive cost tear-down reports (see below). The slope of the learning curve is derived from the progress ratio of manufacturing automotive and other mobile source technologies.

(2) Deriving the Progress Ratio Used in this Analysis

Learning curves vary among different types of manufactured products. Progress ratios can range from 70 to 100 percent, where 100 percent indicates no learning can be achieved.[558] Learning effects tend to be greatest in operations where workers often touch the product, while effects are less substantial in operations consisting of more automated processes. As automotive manufacturing plant processes become increasingly automated, a progress ratio towards the higher end would seem more suitable. The agencies incorporated findings from automotive cost-teardown studies with EPA's literature review of learning-related studies to estimate a progress ratio used to determine learning schedules of fuel economy improving technologies.

EPA's literature review examined and summarized 20 studies related to learning in manufacturing industries and mobile source manufacturing.[559] The studies focused on many industries, including motor vehicles, ships, aviation, semiconductors, and environmental energy. Based on several criteria, EPA selected five studies providing quantitative analysis from the mobile source sector (progress ratio estimates from each study are summarized in

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[557] *Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles*, National Research Council of the National Academies (2015), available at https://www.nap.edu/resource/21744/deps_166210.pdf.
[558] Martin, J., "What is a Learning Curve?" Management and Accounting Web, University of South Florida, available at: https://www.maaw.info/LearningCurveSummary.htm.
[559] *Cost Reduction through Learning in Manufacturing Industries and in the Manufacture of Mobile Sources*, United States Environmental Protection Agency (2015). Prepared by ICF International and available at https://19january2017snapshot.epa.gov/sites/production/files/2016-11/documents/420r16018.pdf.

Table VI-19

Table VI-19, below). Further, those studies expand on Wright's Learning Curve function by using cumulative output as a predictor variable, and unit cost as the response variable. As a result, EPA determined a best estimate of 84 percent as the progress ratio in mobile source industries. However, of those five studies, EPA at the time placed less weight on the *Epple et al. (1991)* study, because of a disruption in learning due to incomplete knowledge transfer from the first shift to introduction of a second shift at a North American truck plant. While learning may have decelerated immediately after adding a second shift, the agencies note that unit costs continued to fall as the organization gained experience operating with both shifts. ~~The agencies now recognize that disruptions are an essential part of the learning process and should not, in and of themselves, be discredited. For this reason,~~ Ithe analysis uses a re-estimated average progress ratio of 85 percent from those five studies (equally-weighted).

Commented [A205]: DELETE: EPA does not agree with this conclusion.

Table VI-19 - Progress Ratios from EPA's Literature Review

Author (Publication Date)	Industry	Progress Ratio (Cumulative Output Approach)
Argote et al. (1997)[560]	Trucks	85%
Benkard (2000)[561]	Aircraft (commercial)	82%
Epple et al. (1991)[562]	Trucks	90%
Epple et al. (1996)[563]	Trucks	85%
Levitt et al. (2013)[564]	Automobiles	82%

In addition to EPA's literature review, this progress ratio estimate was informed based on NHTSA's findings from automotive cost-teardown studies. NHTSA routinely performs evaluations of costs of previously issued Federal Motor Vehicle Safety Standards (FMVSS) for new motor vehicles and equipment. NHTSA's engages contractors to perform detailed engineering "tear-down" analyses for representative samples of vehicles, to estimate how much specific FMVSS add to the weight and retail price of a vehicle. As part of the effort, cost and production volume are examined for automotive safety technologies. In particular, the agency estimated costs from multiple cost tear-down studies for technologies with actual production data

[560] Argote, L., Epple, D., Rao, R. D., & Murphy, K., *The acquisition and depreciation of knowledge in a manufacturing organization - Turnover and plant productivity*, Working paper, Graduate School of Industrial Administration, Carnegie Mellon University (1997).
[561] Benkard, C. L., *Learning and Forgetting - The Dynamics of Aircraft Production*, The American Economic Review, Vol. 90(4), pp. 1034–54 (2000).
[562] Epple, D., Argote, L., & Devadas, R., *Organizational Learning Curves - A Method for Investigating Intra-Plant Transfer of Knowledge Acquired through Learning by Doing*, Organization Science, Vol. 2(1), pp. 58–70 (1991).
[563] Epple, D., Argote, L., & Murphy, K., *An Empirical Investigation of the Microstructure of Knowledge Acquisition and Transfer through Learning by Doing*, Operations Research, Vol. 44(1), pp. 77–86 (1996).
[564] Levitt, S. D., List, J. A., & Syverson, C., *Toward an Understanding of Learning by Doing - Evidence from an Automobile Assembly Plant*, Journal of Political Economy, Vol. 121 (4), pp. 643-81 (2013).

from the *Cost and weight added by the Federal Motor Vehicle Safety Standards for MY 1968-2012 passenger cars and LTVs* (2017).[565]

NHTSA chose five vehicle safety technologies with sufficient data to estimate progress ratios of each, because these technologies are large-volume technologies and are used by almost all vehicle manufacturers. Table VI-20Table VI-20 below includes these five technologies and yields an average progress rate of 92 percent:

Table VI-20 - Progress Ratios Researched by NHTSA

Technology	Progress Ratio
Anti-lock Brake Systems	87%
Driver Airbags	93%
Manual 3-pt lap shoulder safety belts	96%
Adjustable Head Restraints	91%
Dual Master Cylinder	95%

For a final progress ratio used in the CAFE model, the five progress rates from EPA's literature review and five progress rates from NHTSA's evaluation of automotive safety technologies results were averaged. This resulted in an average progress rate of approximately 89 percent. Equal weight was placed on progress ratios from all 10 sources. More specifically, equal weight was placed on the *Epple et al. (1991)* study, because disruptions have more recently been recognized as an essential part in the learning process, especially in an effort to increase the rate of output. Further discussion of how the progress ratios were derived for this analysis is located in [FRIA Chapter X].

ICCT commented that the choice to use safety technology as a model for fuel efficiency led to lower learning rates in the NPRM analysis compared to prior analyses.[566] ICCT stated that safety technologies were chosen for the NPRM because they are used by almost every manufacturer, in contrast to fuel efficiency technologies, where not every manufacturer will use

[565] Simons, J. F., *Cost and weight added by the Federal Motor Vehicle Safety Standards for MY 1968-2012 Passenger Cars and LTVs* (Report No. DOT HS 812 354). Washington, D.C. - National Highway Traffic Safety Administration (November 2017), at pp. 30-33.
[566] NHTSA-2018-0067-11741.

them, particularly when they are first introduced. ICCT stated that to show the impact of changing learning rates, the agencies should run a sensitivity analysis using the learning rates in the TAR, as well as EPA's learning rates in its Final Determination. ICCT concluded that "[w]ithout doing so and without conducting a peer review of the change in approach, it appears clear the agencies have decided to switch to a new costing method that affects all future costs, but without any significant research justification, vetting, or review."

The agencies' selection of a progress rate of 0.89 is based on an average of findings across research and literature reviews conducted by NHTSA and EPA. The EPA cited rates were derived from five studies selected from a sample of 20 transportation modal learning studies that were examined by an EPA contractor, ICF International.[567] One of these 5 studies (Benkard (2000) examines learning in the commercial aircraft industry, which the author notes has many unique features that influence marginal costs. It also has the lowest progress rate. We note that EPA regulates all mobile sources, and while the inclusion of non-passenger vehicle studies in their report was justified, it may have biased the estimate of learning attributable to the motor vehicle industry. Notably, nearly all of the other studies included in the ICF International study found progress rates higher than the 0.84 rate selected by the authors at that time. In reviewing the ICF study, NHTSA found many other studies not included in the report, including many specific to the motor vehicle and environmental technology industries. Over 90 percent of those studies indicated higher progress ratios than ICF recommended.[568] Our current approach includes a broader and more representative sample of these studies rather than the narrow sample selected by ICF.

Commented [A206]: REVISE: Factually incorrect. EPA has not come to these conclusions. EPA stands behind the work done by the subject matter expert on our 2018 contracted study, Dr. Linda Argote, one of the foremost experts on industrial learning. EPA-420-R-16-018.

The agencies do not agree that safety technologies are adopted by all manufacturers at an early stage. Most safety technologies are initially offered as options or standard equipment on only a small segment of the vehicle fleet, typically luxury vehicles. After a number of years, these technologies may be adopted on less expensive vehicles, and eventually they will become required equipment on all vehicles, but the production process is gradual, as it is with fuel efficiency technologies. FMVSS are necessarily established as performance standards- -and automakers are free to develop or choose from existing technologies to achieve such performance requirements—much like automakers can develop or choose from a number of established fuel efficiency technologies to achieve fuel economy requirements. Further, the derivation of progress ratios is based on the concept of a doubling of cumulative production, not time. Therefore, even if production continues at a different pace, it should not disqualify non-fuel efficiency studies. Moreover, the derivation of the progress ratio used in the TAR and Final

[567] *Cost Reduction through Learning in Manufacturing Industries and in the Manufacture of Mobile Sources.* United States Environmental Protection Agency. Prepared by ICF International and available at: https://19january2017snapshot.epa.gov/sites/production/files/2016-11/documents/420r16018.pdf.

[568] See, for example, progress ratios of multiple technologies referenced in The Carbon Productivity Challenge: Curbing Climate Change and Sustaining Economic Growth, McKinsey Climate Change Special Initiative, McKinsey Global Institute, June 2008 (quoting from UC Berkeley Energy Resource Group, Navigant Consulting) and Technology Innovation for Climate Mitigation and its Relation to Government Policies, Edward S. Rubin, Carnegie Mellon University, Presentation to the UNFCCC Workshop on Climate Change Mitigation, Bonn, Germany, June 19, 2004.

Determination document were not confined to fuel efficiency technologies. In fact, as noted above, they even included at least one entirely unrelated study of the aircraft industry.

Finally, we note that the previous learning schedules used in the TAR and EPA's Final Determination were only developed through 2025, whereas this final rule projects learning through 2050. The previous learning schedules are thus not directly compatible with the analysis conducted in this Final Rule, making a sensitivity analysis problematic.

(3) Obtaining Appropriate Baseline Years for Direct Manufacturing Costs to Create Learning Curves

Direct manufacturing costs for each fuel economy improving technology were obtained from various sources, as discussed above. To establish a consistent basis for direct manufacturing costs in the rulemaking analysis, each technology cost is adjusted to MY 2018 dollars. For each technology, the DMC is associated with a specific model year, and sometimes a specific production volume, or cumulative production volume. The base model year is established as the MY in which direct manufacturing costs were assessed (with learning factor of 1.00). With the aforementioned data on cumulative production volume for each technology and the assumption of a 0.89 progress ratio for all automotive technologies, the agencies can solve for an implied cost for the first unit produced. For some technologies, the agencies used modestly different progress ratios to match detailed cost projections if available from another source (for instance, batteries for plugin hybrids and battery electric vehicles).

This approach produced reasonable estimates for technologies already in production, and some additional steps were required to set appropriate learning rates for technologies not yet in production. Specifically, for technologies not yet in production in MY 2017(the baseline analysis fleet), the cumulative production volume in MY 2017 is zero, because manufacturers have not yet produced the technologies. For pre-production cost estimates in the NPRM, the agencies often relied on confidential business information sources to predict future costs. Many sources for pre-production cost estimates include significant learning effects, often providing cost estimates assuming high volume production, and often for a timeframe late in the first production generation or early in the second generation of the technology. Rapid doubling and re-doubling of a low cumulative volume base with Wright's learning curves can provide unrealistic cost estimates. In addition, direct manufacturing cost projections can vary depending on the initial production volume assumed. Accordingly, the agencies carefully examined direct costs with learning, and made adjustments to the starting point for those technologies on the learning curve to better align with the assumptions used for the initial direct cost estimate.

Commented [A207]: REVISE: Factually incorrect

(4) Cost Learning as Applied in the CAFE Model

For the NPRM analysis, the agencies updated the manner in which learning effects apply to costs. In the Draft TAR analysis, the agencies had applied learning curves only to the incremental direct manufacturing costs or costs over the previous technology on the tech tree. In practice, two things were observed: (1) if the incremental direct manufacturing costs were positive, technologies could not become less expensive than their predecessors on the technology tree, and (2) absolute costs over baseline technology depended on the learning curves of root

technologies on the technology tree. For the NPRM and final rule analysis, the agencies applied learning effects to the incremental cost over the null technology state on the applicable technology tree. After this step, the agencies calculated year-by-year incremental costs over preceding technologies on the tech tree to create the CAFE model inputs. As discussed below, for the final rule, the agencies revised the CAFE model to replace incremental cost estimates with absolute estimates, each specified relative to the null technology state on the applicable technology tree. This change facilitated quality assurance and is expected to make cost inputs more transparently relatable to detailed model output. Likewise, this change made it easier to apply learning curves in the course of developing inputs to the CAFE model.

Commented [A208]: REVISE: EPA was not technically engaged in the work described here.

Each technology in the CAFE Model is assigned a learning schedule developed from the methodology explained previously. For example, the following chart shows learning rates for several technologies applicable to midsize sedans, demonstrating that while the agencies estimate that such learning effects have already been almost entirely realized for engine turbocharging (a technology that has been in production for many years), we estimate that significant opportunities to reduce the cost of the greatest levels of mass reduction (*e.g.*, MR5) remain, and even greater opportunities remain to reduce the cost of batteries for HEVs, PHEVs, BEVs. In fact, for certain advanced technologies, the agencies determined that the results predicted by the standard learning curves progress ratio was not realistic, based on unusual market price and production relationships. For these technologies, the agencies developed specific learning estimates that may diverge from the 0.89 progress rate. These include:

[Text Forthcoming]

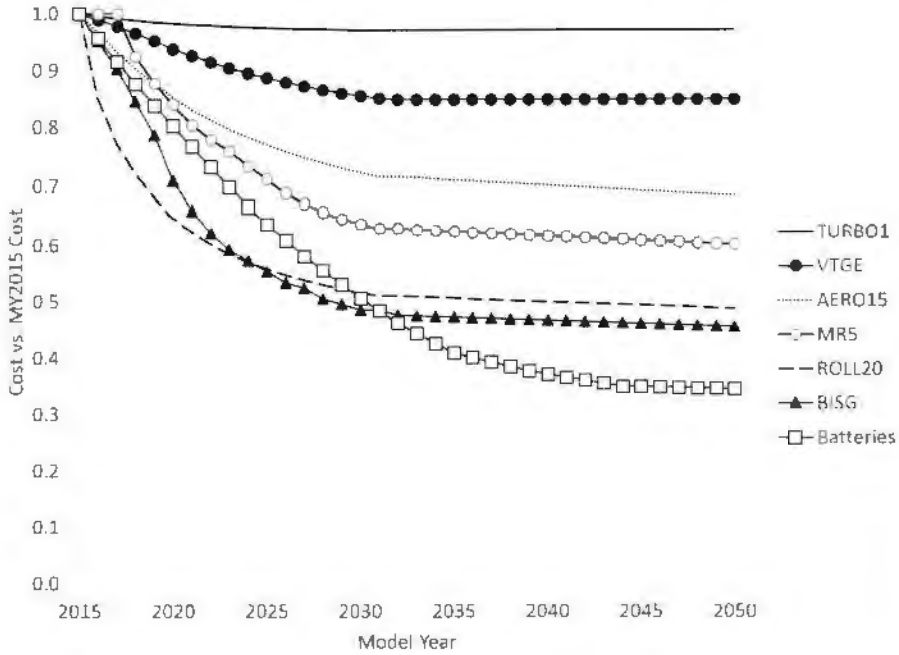

Figure VI-7 – Examples of Year-by-Year Cost Learning Effects (Midsize Sedan)

(5) Text and Table ForthcomingPotential Future Approaches to Considering Cost Learning in the CAFE Model

As discussed above, cost inputs to the CAFE model incorporate estimates of volume-based learning. As an alternative approach, the agencies have considered modifications to the CAFE model that would calculate degrees of volume-based learning dynamically, responding to the model's application of affected technologies. While it is intuitive that the degree of cost reduction achieved through experience producing a given technology should depend on the actual accumulated experience (*i.e.*, volume) producing that technology, such dynamic implementation in the CAFE model is thus far infeasible. Insufficient data have been available regarding manufacturers' historical application of specific technology. Further, insofar as the agencies' estimates of underlying direct manufacturing costs already make some assumptions about volume and scale, insufficient information is currently available to determine how to dynamically adjust these underlying costs. It should be noted that if learning responds dynamically to volume, and volume responds dynamically to learning, an internally consistent model solution would likely require iteration of the CAFE model to seek a stable solution within

Commented [A209]: REVISE: EPA is not considering future changes to the CAFE model.

the model's representation multiyear planning. As discussed below, the CAFE model now supports iteration to balance vehicle cost and fuel economy changes with corresponding changes in sales volumes, but, this iteration is not yet implemented in a manner that would necessarily support the balance of learning effects on a multiyear basis. The agencies invited comment on the issue, seeking data and methods that would provide the basis for a practicable approach to doing so. Having reviewed comments on cost learning effects, the agencies conclude it remains infeasible to calculate degrees of volume-based learning in a manner that responds dynamically to modeled technology application. The agencies will continue to examine this issue for future development.

e) Cost Accounting

The CAFE model applied for the NPRM analysis used an incremental approach to specifying technology cost estimates, such that the cost for any given technology was specified as an incremental value, relative to the technology immediately preceding on the relevant technology pathway. For example, the cost of a 7-speed transmission was specified as an amount beyond the cost of a 6-speed transmission. This approach necessitated careful dynamic accounting for the progressive application of the technology as the model worked on a step-by-step basis to "build" a technology solution. As discussed in the corresponding model documentation, the model included complex logic to "back out" some of these costs carefully when, for example, replacing a conventional powertrain with a hybrid-electric system.[569]

To facilitate specification of detailed model inputs and review of detailed model outputs, today's CAFE model replaces incremental cost inputs with absolute cost inputs, such that the estimated cost of each technology is specified relative to a common reference point for the relevant technology pathway. For example, the cost of the above-mentioned 7-speed transmission is specified relative to a 4-speed transmission, as is the cost of every other transmission technology. This change in the structure of cost inputs does not, by itself, change model results, but it does make the connection between these inputs and corresponding outputs more transparent. Model documentation accompanying today's analysis presents details of the updated structure for model cost inputs.[570]

6. [Text Forthcoming]

C. The model applies technologies based on a least-cost technology pathway to compliance, given the framework above

The CAFE model, discussed in detail above, is designed to simulate compliance with a given set of CAFE or tailpipe CO_2 emissions standards for each manufacturer that sells vehicles in the United States. For the final rule analysis, the model began with a representation of the MY 2017 vehicle model offerings for each manufacturer that included the specific engines and transmissions on each model variant, observed sales volumes, and all fuel economy improving technology that is already present on those vehicles. From there the model added technology, in

[569] NHTSA, Draft CAFE Model Documentation, July 2018, at 42-46. Available at https://www.nhtsa.gov/corporate-average-fuel-economy/compliance-and-effects-modeling-system.
[570] [Text Forthcoming].

response to the standards being considered, in a way that minimized the cost of compliance and reflected many real-world constraints faced by automobile manufacturers. The model addressed fleet year-by-year compliance, taking into consideration vehicle refresh and redesign schedules and shared platforms, engines, and transmissions among vehicles.

The agencies evaluated a wide array of technologies manufacturers could use to improve the fuel economy of new vehicles, in both the immediate future and during the timeframe of this rulemaking, to meet the fuel economy and CO_2 standards. The agencies evaluated costs for these technologies, and looked at how these costs may change over time. The agencies also considered how fuel-saving technologies may be used on many types of vehicles (ranging from small cars to trucks) and how the technologies may perform in improving fuel economy and CO_2 emissions in combination with other technologies. With cost and effectiveness estimates for technologies, the agencies forecast how manufacturers may respond to potential standards and can estimate the associated costs and benefits related to technology and equipment changes. This assists the assessment of technological feasibility and is a building block for the consideration of economic practicability of the standards.

The agencies described in the NPRM that the characterization of current and anticipated fuel-saving technologies relied on portions of the analysis presented in the Draft TAR, in addition to new information that had been gathered and developed since conducting that analysis, and the significant, substantive input that was received during the Draft TAR comment period. The Draft TAR considered many technologies previously assessed in the 2012 final rule;[571] in some cases, manufacturers have nearly universally adopted a technology in today's new vehicle fleet (for example, electric power steering), but in other cases, manufacturers only occasionally use a technology in today's new vehicle fleet (like turbocharged engines). For a few technologies considered in the 2012 rulemaking, manufacturers began implementing the technologies but have since largely pivoted to other technologies due to consumer acceptance issues ((for instance, drivability and performance feel issues associated with some dual clutch transmissions without a torque converter) or limited commercial success.

In some cases, EPA and NHTSA presented different analytical approaches in the Draft TAR. However, for the NPRM and final rule analysis, the agencies harmonized their analytical approach to use one set of effectiveness values (developed with one tool), one set of cost assumptions, and one set of assumptions about the limitations of some technologies. To develop these assumptions, the agencies evaluated many sources of data, in addition to many stakeholder comments received on the Draft TAR. The preferred approach was to harmonize on sources and methodologies that were data-driven and reproducible for independent verification, produced using tools utilized by OEMs, suppliers, and academic institutions, and using tools that could support both CAFE and CO_2 analysis. As the agencies noted in the NPRM, a single set of assumptions also facilitates and focuses public comment by reducing burden on stakeholders who seek to review all of the supporting documentation for this proposal.

The agencies identified a preference to use values developed from careful review of commercialized technologies; however, in some cases for technologies that are new, and are not

[571] 77 FR 62624 (Oct. 15, 2012).

yet for sale in any vehicle, the analysis relied on information from other sources, including CBI and third-party research reports and publications. The agencies strived to keep the technology analysis as current as possible in light of the ongoing technology development and implementation in the automotive industry. Additional emerging technologies added for the final rule analysis are described in further detail, below.

The agencies' process to develop effectiveness assumptions is described in detail in [Section Effectiveness], above, but to summarize, both the NPRM and final rule analysis modeled more than 50 fuel economy-improving technologies, and combinations thereof, on 10 vehicle types (an increase from five vehicle types in NHTSA's Draft TAR analysis). While 10 vehicle types may seem like a small number, a large portion of the production volume in the analysis fleet has specifications that are very similar, especially in highly competitive segments (for instance, many mid-sized sedans, many small SUVs, and many large SUVs coalesce around similar specifications, respectively), and baseline simulations have been aligned around these modal specifications. The sequential addition of these technologies generated more than 100,000 unique technology combinations per vehicle class. Because the analysis included 10 technology classes, more than one million full-vehicle simulations were run. In addition, simulation modeling was conducted to determine the appropriate amount of engine downsizing needed to maintain baseline performance across all modeled vehicle performance metrics when advanced mass reduction technology or advanced engine technology was applied, so these simulations take into account performance neutrality, given logical engine down-sizing opportunities associated with specific technologies.

Some baseline vehicle assumptions used in the simulation modeling were updated based on public comment and the assessment of the NPRM and final rule analysis fleets. The agencies updated assumptions about curb weight, component inertia, as well as technology properties like baseline rolling resistance, aerodynamic drag coefficients, and frontal areas. Many of the assumptions are aligned with published research from the Department of Energy's Vehicle Technologies Office and other independent sources.[572] Additional transmission technologies and more levels of aerodynamic technologies than NHTSA presented in the Draft TAR analysis were also added for the analysis. Having additional technologies in the model allowed the agencies to assign baselines and estimate fuel-savings opportunities with more precision.

To develop technology cost assumptions, the agencies estimated present and future costs for fuel-saving technologies, taking into consideration the type of vehicle, or type of engine if technology costs vary by application. Since the 2012 final rule, many cost assessments, including tear down studies, were funded and completed, and presented as part of the Draft TAR analysis. These studies evaluated transmissions, engines, hybrid technologies, and mass reduction.[573] ~~As a result, t~~The NPRM and final rule analyses use the Draft TAR's~~s updated~~ cost

[572] *See, e.g.*, Pannone, G. "Technical Analysis of Vehicle Load Reduction Potential for Advanced Clean Cars," April 29, 2015. *Available at* https://www.arb.ca.gov/research/apr/past/13-313.pdf. Last accessed December 28, 2019.
[573] FEV prepared several cost analysis studies for EPA on subjects ranging from advanced 8-speed transmissions to belt alternator starter, or Start/Stop systems. NHTSA also contracted with Electricore, EDAG, and Southwest Research on teardown studies evaluating mass reduction and transmissions. The 2015 NAS report on fuel economy technologies for light-duty vehicles also evaluated the agencies' technology costs developed based on these

estimates for many technologies. In addition to those studies, the analysis also leveraged research reports from other organizations to assess costs.[574] The analysis also used an updated, peer-reviewed model developed by ANL for the Department of Energy ~~to provide a more rigorous estimate for battery costs~~consistent with past analyses. This model, BatPaC, provides an estimate future for battery costs for hybrids, plug-in hybrids, and electric vehicles, taking into account the different battery design characteristics and taking into account the size of the battery for different applications.[575] The agencies updated technology costs for the NPRM to 2016 dollars, because, as in many cases, technology costs were estimated several years ago, and since then have further updated technology costs to 2018 dollars for the final rule.

Commented [A210]: CHANGE AS SHOWN: Clarifying text.

Commented [A211]: CHANGE AS SHOWN: It is not factual, and it is misleading, to refer to using BatPac in the SAFE rule as "more rigorous" when all past GHG/CAFE analyses have used BatPac.

Cost and effectiveness values were estimated for each technology included in the analysis. As mentioned above, more than 50 technologies were considered in the NPRM and final rule analyses, and the agencies evaluated many combinations of these technologies on many applications. In the NPRM, the agencies identified overarching potential issues in assessing technology effectiveness and cost, including:

- *Baseline vehicle technology level assessed as too low, or too high.* Compliance information was extensively reviewed and supplemented with available literature on the vehicle models considered in the analysis fleet. Manufacturers could also review the baseline technology assignments for their vehicles, and the analysis incorporates feedback received from manufacturers.

- *Technology costs too low or too high.* Tear down cost studies, CBI, literature, and the 2015 NAS study information were referenced to estimate technology costs. In cases where one technology appeared to exceed all other technologies on cost and effectiveness, information was acquired from additional sources to confirm or reject assumptions. Cost assumptions for emerging technologies were reassessed in cases where new information became available.

- *Technology effectiveness too high or too low in combination with other vehicle technologies.* Technology effectiveness was evaluated using the Autonomie full-vehicle simulation modeling, taking into account the impact of other technologies on the vehicle and the vehicle type. Inputs and modeling for the analysis took into account laboratory test data for production and some pre-production technologies, technical publications, manufacturer and supplier CBI, and simulation modeling of specific technologies. Evaluating recently introduced production products to inform the technology effectiveness models of emerging technologies was preferred; however, some technologies that are not yet in production were considered using CBI. Simulation

teardown studies, and the technology costs used in this proposal were updated accordingly. These studies are discussed in detail in Chapter [XXX] of the FRIA.

[574] For example, the agencies relied on reports from the Department of Energy's Office of Energy Efficiency & Renewable Energy's Vehicle Technologies Office. More information on that office is available at https://www.energy.gov/eere/vehicles/vehicle-technologies-office. Other agency reports that were relied on for technology or other information are referenced throughout this proposal and accompanying PRIA.

[575] For instance, battery electric vehicles with high levels of mass reduction may use a smaller battery than a comparable vehicle with less mass reduction technology and still deliver the same range on a charge.

modeling used carefully chosen baseline configurations to provide a consistent, reasonable reference point for the incremental effectiveness estimates.

- *Vehicle performance not considered or applied in an infeasible manner.* Performance criteria, including low speed acceleration (0-60 mph time), high speed acceleration (50-80 mph time), towing, and gradeability (six percent grade at 65 mph) were also considered. In the simulation modeling, resizing was applied to achieve the same performance level as the baseline for the least capable performance criteria but only with significant design changes. The analysis struck a balance by employing a frequency of engine downsizing that took product complexity and economies of scale into account.

- *Availability of technologies for production application too soon or too late.* A number of technologies were evaluated that are not yet in production. CBI was gathered on the maturity and timing of these technologies and the cadence at which manufacturers could adopt these technologies.

- *Product complexity and design cadence constraints too low or too high.* Product platforms, refresh and redesign cycles, shared engines, and shared transmissions were also considered in the analysis. Product complexity and the cadence of product launches were matched to historical values for each manufacturer.

- *Customer acceptance under estimated or over estimated.* Resale prices for hybrid vehicles, electric vehicles, and internal combustion engine vehicles were evaluated to assess consumer willingness to pay for those technologies. The analysis accounts for the differential in the cost for those technologies and the amount consumers have actually paid for those technologies. Separately, new dual-clutch transmissions and manual transmissions were applied to vehicles already equipped with these transmission architectures.

The agencies sought comments on all assumptions for fuel economy technology costs, effectiveness, availability, and applicability to vehicles in the fleet.

Several commenters compared the technology effectiveness and cost estimates from prior rulemaking actions to the NPRM, some commenting that the NPRM analysis represented a better balance of input from all stakeholders regarding the potential cost and benefits of future fuel efficient technologies,[576] and some commenting that the NPRM analysis represented a step back from the Draft TAR and EPA's Proposed Determination in terms of both the analysis itself and the resulting conclusions about the level of technology required to meet the augural standards.[577] Specifically, while some commenters stated that the Draft TAR and subsequent EPA midterm review documents had recently concluded that augural standards were achievable with very low levels of electrification based on currently available information on technology effectiveness and

[576] *See, e.g.*, NHTSA-2018-0067-11928.
[577] *See, e.g.*, NHTSA-2018-0067-11873.

cost,[578] other commenters reiterated that conventional gasoline powertrains alone were insufficient to achieve post-2021 model year targets.[579]

Generally, the automotive industry supported the agencies' NPRM analysis over previous analyses. In addition to the automotive industry's support of the agencies' use of one modeling tool for analysis, discussed in [Section P04], above, the industry also commented in support of specific technology effectiveness, cost, and adoption assumptions used in the updated analysis.

For example, the Alliance commented that the analysis appropriately restricted the application of some technologies, like the application of low rolling resistance tires on performance vehicles, and limited aerodynamic improvements for trucks and minivans.[580] Similarly, the Alliance commented in support of the decision to exclude HCR2 technology from the analysis, citing previous comments stating that "the inexplicably high benefits ascribed to this theoretical combination of technologies has not been validated by physical testing."

Ford commented more broadly that "[t]he previous analyses performed by the Agencies too often selected technology benefits from the high-end of the forecasted range, and cost from the lower-end, in part because deference was given to supplier or other third-party claims over manufacturers' estimates."[581] Ford noted that, "[m]anufacturer estimates, while viewed as conservative by some, are informed by years of experience integrating new technologies into vehicle systems in a manner that avoids compromising other important attributes (NVH, utility, safety, etc.)," continuing that "[t]he need to preserve these attributes often limits the actualized benefit of a new technology, an effect insufficiently considered in projections from most non-OEM sources." Ford concluded, as mentioned above, that the NPRM analysis better balanced these considerations.

Toyota commented that the discrepancy between the automotive industry and prior regulatory assessments stemmed from "agency modeling relying on overly optimistic assumptions about technology cost effectiveness and deployment rates."[582] Toyota pointed to a prior analysis that projected compliance for Toyota's MY 2025 lineup using the ALPHA model as an example of how "the agency's analysis failed to account for customer requirements (cost, power, weight-adding options, etc.) that erode optimal fuel economy, and normal business considerations that govern the pace of technology deployment." In contrast, Toyota stated that the "[m]odeled technology cost, effectiveness, and compliance pathways in the proposed rulemaking rely on more recent data as well as more realistic assumptions about the level of technology already on the road today, the pace of technology deployment, and trade- offs between vehicle efficiency and customer requirements."

Honda, in its feedback on the models used in the standard setting process, commented that "the current version of the CAFE model is reasonably accurate in terms of technology

[578] *See, e.g.*, NHTSA-2018-0067-11969.
[579] *See, e.g.*, NHTSA-2018-0067-12150.
[580] NHTSA-2018-0067-12073, at 134.
[581] NHTSA-2018-0067-11928.
[582] NHTSA-2018-0067-12150.

efficiency, cost, and overall compliance considerations, and reflects a notable improvement over previous agency modeling efforts conducted over the past few years."[583]

FCA commented in recognition of the CAFE model improvements over the Draft TAR version, but noted they "continue to believe that the cost and benefits used as inputs to the model are overly optimistic."[584] FCA used its updated Jeep Wrangler Unlimited and Ram 1500 pickup models as examples of vehicles that "provide real life examples of the costs and benefits that can be achieved with fuel and weight saving technology"; however, "after all of the real world concerns such as emissions, drivability, OBD, and fuels are considered, the benefits observed remain less than those derived by the Antonomie model and used as inputs to the Volpe model."

Conversely, environmental groups, consumer groups, and some States and localities commented that the Draft TAR and subsequent EPA analyses were more representative of the current state of vehicle technologies. These groups all generally commented, in different terms, that the NPRM analysis technology effectiveness was understated and technology costs were overstated, and additional constraints the agencies placed on the analysis, like excluding technologies already in production or constraining technology pathways, also helped lead to that result.[585]

ICCT commented that the agencies "ignored their own rigorous 2015-2017 technological assessment, and have adopted a series of invalid and unsupportable decisions which artificially constrain the availability and dramatically under-estimate levels of effectiveness of many different fuel economy improvement and [CO_2]-reduction technologies and unreasonably increase modeled compliance costs."[586] ICCT also commented that the agencies ignored, suppressed, dismissed, or restricted the use of work done to update technologies and technology cost and effectiveness assessments since the 2012 final rule for MYs 2017-2025. ICCT stated that the "invalid high cost result [of the modeled augural standards in 2025] was created by the agencies by making many dozens of unsupported changes in the technology effectiveness and availability inputs, the technology cost inputs, and the technology package constraints." ICCT stated that "the agencies failed to capture the latest available information and, as a result, their assessment incorrectly and artificially overstates technology costs."

CARB commented that the agencies did not present sufficient new evidence to change previous technical findings, specifically in regards to conventional vehicle technologies.[587] CARB stated that instead of relying on new information, as had been asserted as justification for the proposal, the analysis was based on older data that did not reflect current technology. Accordingly, CARB pointed out that previous analysis by the agencies projected far less need for electrification than what was required in the proposal, stating that the underlying cause is a reduction in the assumed cumulative improvements for what advanced gasoline technology is able to achieve.

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[583] NHTSA-2018-0067-11818.
[584] NHTSA-2018-0067-11943.
[585] NHTSA-2018-0067-11873; NHTSA-2018-0067-11984.
[586] NHTSA-2018-0067-11741 full comments.
[587] NHTSA-2018-0067-11873.

A coalition of States and Cities similarly commented that "[t]he Agencies' conclusions regarding the technology necessary to meet the 2025 standards and the cost of that technology run counter to the evidence before the agency, diverge from prior factual findings without explanation and without transparency as to the source of data relied on, and are unsupported by any reasoned analysis. Such analysis bears many hallmarks of an arbitrary and capricious action."[588]

Roush Industries, commenting on behalf of CARB, commented that "the 2018 PRIA projected average costs for technology implementation to achieve the existing standards to be significantly overstated and in conflict with the 2016 Draft TAR cost estimates generated by the Agencies only two years earlier."[589] Roush commented that the Draft TAR analyses of cost and incremental fuel economy improvement necessary to achieve the augural standards was consistent with Roush's own estimates and other published data.

Similarly, H-D Systems (HDS), commenting on behalf of the California DOJ, commented that "the estimates in the 2016 TAR on technology cost and effectiveness still represent the correct estimates based on the latest available data."[590] HDS, in its analysis of the costs of technologies to meet different potential standards between the Draft TAR and the NPRM, noted that "costs for most conventional (i.e., non-electric) drivetrain technologies were similar in both reports in that costs were within +5% of the average of the costs from the two reports. The only exception was the cost estimate for the High CR second generation Atkinson cycle or HCR2 engine which was estimated to be much more expensive. Due to differences in nomenclature, transmission technology costs could not be directly compared but were similar at the highest efficiency level. In contrast, cost of hybrid technology was estimated to be much higher in the PRIA and were 200 to 250% higher for strong hybrids. Costs of drag reduction, rolling resistance reduction and auxiliary system technologies were also quite similar but the cost of mass reduction was substantially higher in the PRIA by a factor of 2 to 3. Costs of engine friction reduction appear not to be included in the cost computation for the PRIA although the technology appears to be integrated into some of the engine technology packages analyzed in the PRIA to estimate effectiveness."

CFA commented that "[t]he overarching discussion of technology developments that introduces the NHTSA analysis is fundamentally flawed and infects the entire proposal," taking issue with the claim that "some options considered in the original order for the National Program ha[d] not worked out as EPA/NHTSA anticipated."[591] CFA commented that the agencies failed to note that some technology options have performed better than anticipated, and "the fact that some technologies have done better than expected is a basis for increasing the standards, not in the context of a mid-term review that was supposed to tweak the long-term program."

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[588] NHTSA-2018-0067-11735 (citing State Farm, 463 U.S. at 43; Fox Television, 556 U.S. at 515; Humane Soc. of U.S. v. Locke, 626 F.3d 1040, 1049 (9th Cir. 2010)).
[589] NHTSA-2018-0067-11984.
[590] NHTSA-2018-0067-11985.
[591] NHTSA-2018-0067-12005.

NCAT commented that the "inflation of projected technology costs does not appear to be attributable primarily to the projected cost of any given technology, but rather to modeling constraints on the application of such technologies to vehicles. Many of these constraints appear to be arbitrary and NHTSA's departure from prior analyses in these respects is not adequately supported."[592]

Environmental groups and States also commented that the agencies either should reincorporate all the Draft TAR or the EPA Proposed and Final Determination analyses' technologies, technology effectiveness values, and technology costs into the analysis, and/or compare the final rule analysis with those prior analyses to show how the updated assumptions changed the results from those prior analyses.

For example, ICCT commented that "[f]or the agencies to conduct a credible regulatory assessment they must remove all the technology availability constraints, re-incorporate and make available the full portfolio of technology options as was available in EPA's analysis for the original 2017 Final Determination, and include at least 15 g/mile CO_2 for off-cycle credits by 2025, to credibly reflect the real-world technology developments in the auto industry."[593] ICCT also stated that "[t]he agencies need to identify each and every technology cost input used in their modeling, and provide a clear engineering and evidence based justification for why that cost differs from the costs employed in the extremely well documented and well justified Draft TAR and in EPA's 2016 TSD and 2017 Final Determination, taking into account the above discussion of significant new evidence developed since those prior estimates were made. Absent such disclosure and justification, the default assumption needs to be that the prior costs estimated based on the most recent data are more appropriate than the estimates used for the proposal."

In additional, groups of commenters were equally split on the ability of technologies to meet different compliance targets. For example, the Alliance commented that "the only technologies that have demonstrated the improvements necessary to meet the MY 2025 standards are strong hybrids, plug-in electric vehicles, and fuel cell electric vehicles. The Agencies' analysis for this Proposed Rule predict the need for significant growth in sales of electrified vehicles, a finding consistent with third-party analyses."[594] In contrast, UCS commented that electrified powertrains "are not especially relevant for the MY 2022-2025 regulations."[595]

The agencies are aware that the prior analyses concluded that compliance with the augural standards could largely be met through advances in gasoline vehicle technologies, and with only very low levels of strong hybrids and electric vehicles. As the agencies stated in the NPRM, consistent with both agencies' statutes, the proposal was entirely *de novo*, based on an entirely new analysis reflecting the best and most up-to-date information available to the agencies at the time of this rulemaking.[596] As discussed in [Sections P04], [Section P06.A], and further below, the NPRM and final rule analyses reflect updates to technology effectiveness estimates, technology costs, and the methodology for applying technologies to vehicles that the

[592] NHTSA-2018-0067-11969.
[593] NHTSA-2018-0067-11741 full comments.
[594] NHTSA-2018-0067-Alliance at 15.
[595] NHTSA-2018-0067-UCS at 23.
[596] 83 FR 42897.

agencies believed better represent the state of technology and the associated costs compared to prior analyses, that result in pathways to compliance that looked both similar and different to those in prior analyses.

That said, several of the effectiveness and cost values used in the NPRM and final rule analysis were directly carried over from the 2012 rule for MYs 2017-2025, Draft TAR, and EPA Midterm Evaluation analyses.[597] Several others were carried over from the 2015 NAS report,[598] which the agencies heavily relied upon in past analyses even if specific cost or effectiveness values were not used. Different technology effectiveness estimates, cost estimates, or adoption constraints were employed where the agencies had information, from technical reports, manufacturers, or other stakeholders, indicating that a technology could or could not be feasibly adopted in the rulemaking timeframe, or a technology could or could not be adopted in the way that the agencies had previously modeled it. Notably, most differences in pathways to compliance are attributable to only a few significant differences between this rulemaking analysis and prior rulemaking analyses.

For example, as discussed above in [Section Effectiveness], for the EPA Draft TAR and Proposed Determination analyses, HCR engine and downsized and turbocharged engine technologies effectiveness was estimated using Tier 2 certification fuel, which has a higher octane rating compared to regular octane fuel.[599, 600, 601] This does not maintain functionality—a key requirement of the agencies' analytical approach—because consumers would incur higher costs for using premium fuel in order to achieve the modeled fuel economy improvements, compared to baseline engines that were replaced, which operated on lower cost regular octane fuel. By not maintaining the fuel octane functionality and vehicle attributes, the EPA Draft TAR and Proposed Determination analyses applied higher effectiveness for these technologies than could be achieved had regular octane fuel been assumed for the HCR and downsized turbocharged engines.

Commented [A212]: DELETE: This is not factually correct. As noted elsewhere in the comments, EPA's benchmarking and modeling of engines is based on BOTH Tier 2 (for certification) and Tier 3 (for calibration in real-world use)

NHTSA's effectiveness analysis for the Draft TAR used some engine maps that were developed with premium octane gasoline, although NHTSA stated at that time that the agency would ensure that all future engine model development is performed with regular grade octane gasoline.[602] Commenters like Ford commented that the effectiveness estimates for turbo downsized engine packages were too high, in part because of the use of high octane fuel, but commented in appreciation of NHTSA's acknowledgement that any subsequent testing would use fuel with the appropriate octane level, as they stated the impact of the change needed to be reflected in future analyses.[603]

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[597] *See, e.g.*, PRIA at 449, 451, 452, 453, 458.
[598] *See, e.g.*, PRIA at 358-360.
[599] Draft TAR at 5-228.
[600] Tier 2 fuel has an octane rating of 93. Typical regular grade fuel has an octane rating of 87 (R+M)/2 octane.
[601] EPA Proposed Determination at 2-209 to 2-212.
[602] Draft TAR at Draft TAR at 5-504, 5-512.
[603] [Ford Motor Company Response to the Draft TAR September 26, 2016 FIND DOCKET ID, at pg. 4].

Engine specifications used to create the engine maps for the NPRM and the final rule were developed using Tier 3 fuel to assure the engines were capable of operating on real world regular octane (87 pump octane = (R+M/2)), similar to what manufacturers have told us they must do to ensure engines have acceptable noise, vibration, harshness, drivability and performance, and are durable and will not fail prematurely when operated on regular octane fuel. This accounts for some of the effectiveness and cost differences for engine technologies between the Draft TAR/Proposed Determination and the NPRM/final rule.[604]

~~The agencies determined the engine maps developed for the NPRM and used in the final rule appropriately account for fuel octane, and provide a superior estimate of real-world fuel efficiency than those used in previous analyses using higher octane fuels. The agencies believe ICCT's and other commenters' assertions that the engine maps should reflect Tier 2 fuel and not be updated for Tier 3 fuel would ignore these important considerations, and would provide engine maps that could not be achieved by engines in the real world. Therefore, the agencies determined that engine maps developed for the Draft TAR and EPA Proposed Determination that were based on Tier 2 fuel should not be used for the NPRM and final rule analyses for these technical reasons.~~

Commented [A213]: DELETE: Again, this is not factually correct. As noted elsewhere in the comments, EPA's benchmarking and modeling of engines is based on BOTH Tier 2 (for certification) and Tier 3 (for calibration in real-world use)

~~As another related example, the agencies described that prior analyses had relied heavily on the availability of the HCR2 (or ATK2) "future" Atkinson Cycle engine as a cost-effective pathway to compliance for stringent alternatives, but many engine experts questioned its technical feasibility and near-term commercial practicability.[605] The agencies explained that EPA staff began theoretical development of this conceptual engine with a best-in-class 2.0L Atkinson cycle engine and then increased the efficiency of the engine map further, through the theoretical application of additional technologies in combination, including cylinder deactivation, engine friction reduction, and cooled exhaust gas recirculation. While the potential of such an engine is interesting, nevertheless the engine remains entirely speculative. No production HCR2/ATK2 engine as outlined in the EPA SAE paper has ever been commercially produced (or even produced as a prototype in a lab setting). Furthermore, the engine map has not been validated with hardware and bench data, even on a prototype level (as no such engine exists to test to validate the engine map).~~

~~Furthermore, vehicle manufacturers had commented on EPA's effectiveness assumptions and estimates of HCR2/ATK2 future penetration levels in the Draft TAR, stating for example that "[t]he effectiveness values for the 'futured' ATK2 package—projected at 40% penetration in 2025MY and includes cooled exhaust gas recirculation (CEGR) and cylinder deactivation (DEAC)—are too high, primarily due to overtly optimistic efficiencies in the base engine map, insufficient accounting of CEGR and DEAC integration losses, and no accounting of the impact of 91RON Tier 3 test fuel," and that "44% fleet-wide penetration of ATK2 in 2025MY is unrealistic given the limited number of powertrain refresh cycles available before 2025MY. In addition, it is unreasonable to assume that OEMs already heavily invested in different high-~~

[604] For more details, *see* Section [engine subsection].
[605] ~~NPRM [illegible]~~

~~efficiency powertrain pathways (e.g., turbo-downsizing) would be able to commit the immense resources needed to reach these high ATK2 penetration levels in such a short time."[606]~~

~~Accordingly, the agencies decided not to include HCR2 technology in the NPRM analysis because there still has been no observable physical demonstration of the speculative technology, and many questions remain about its practicability as specified, especially in high load, low engine speed operating conditions. So, where previous analyses demonstrated pathways to compliance with only advanced gasoline vehicle technologies—indeed, relying heavily on HCR2/ATK2 as a pathway to compliance—the removal of HCR2/ATK2 in the NPRM and final rule analyses introduced the opportunity for more strong hybrid and full battery electric vehicles to be used as a pathway to compliance.~~

As another example, further discussed in [Section Fleet], the agencies had traditionally taken different approaches to assigning baseline road load reduction technology assignments. For analyzing baseline levels of mass reduction in an analysis fleet, NHTSA had developed for the Draft TAR a regression model to summarize a vehicle's weight savings using a relative performance approach and accounting for vehicle content, using cost curves developed from teardown studies of a MY 2011 Honda Accord and MY 2014 Chevrolet Silverado pickup truck. ~~EPA developed its own methodology that classified vehicles based on weight reductions from a MY 2008 vehicle, compared to the MY 2014 version of the same vehicle, using a cost curve from a tear-down study of a MY 2010 Toyota Venza. This study included an assumption that the vehicle's wheels could be redesigned to a lower baseline weight with no additional costs, despite a more complicated production process required to do so. One notable difference between the methodologies was that vehicles designated as having no mass reduction technology in the EPA analysis would incur negative costs when moving from zero mass reduction technology to the first level of mass reduction technology. NHTSA's approach, carried forward to the NPRM and final rule, sets baseline mass reduction assignments so that costs of implementing mass reduction technologies are fully ascribed in the overall vehicle technology costs.~~

The agencies also included additional advanced powertrain technologies and other vehicle-level technologies in the technology pathways between the Draft TAR and NPRM, and between the NPRM and final rule. However, manufacturers and suppliers have repeatedly told the agencies that there are diminishing returns to increasing the complexity of advanced gasoline engines, including in the amount of fuel efficiency benefit that they can provide. For example, Toyota commented, in response to the EPA SAE paper benchmarking the 2018 Camry with the 2.5L Atkinson-cycle engine and "futuring" midsize exemplar vehicles based on the generated engine map,[607] that although EPA's addition of cylinder deactivation to the hypothetical 2025 exemplar vehicle is technically possible and would provide some fuel economy and CO_2 benefit, the primary function of cylinder deactivation is to reduce engine pumping losses which the Atkinson cycle and EGR already accomplish on the 2018 Camry.[608] Toyota concluded, "The overlapping and redundant measures to reduce engine pumping losses would add costs with

Commented [A214]: **DELETE:** Same comment as above

Commented [A215]: **DELETE:** While EPA is confident in the incremental improvements available to the 2012 vintage Atkinson technology (HCR1 to HCR2), EPA still conducted a sensitivity analysis, removing HCR2 from the list of technologies. The results continued to show that relatively little change in the required technology costs and additional need for strong electrification, so the characterization of "rely heavily"is not accurate.

Commented [A216]: **DELETE:** The text in these paragraphs appears to be well out-of date, and is factually incorrect to describe the combination of Atkinson cycle and CEGR + deac as "speculative." First, that exact combination was indeed validated with bench data. Second, CEGR was introduced in 2018 on a production Atkinson cycle engine with the Toyota Camry. Additioal benefits of cylinder deactivation were realtively easy to confirm using bench tests.

Commented [A217]: **DELETE:** This is not an accurate characterization of EPA's approach to assigning levels of mass reduction available to vehicles in the initial fleet. In any case, it is not necessary in order to describe the approach used by NHTSA for the FRM anlaysis.

Commented [A218]: **DELETE:** It is indeed true that some MY2008 vintage vehicles had oppurtinity for cost-saving mass reduction, it is also true that today very few vehicles are starting from the same point. EPA's mass reduction methodology places each vehicle along the mass reduction cost curve, depending on the particular characteristics of the vehicle.

~~[606] [Ford Motor Company Response to the Draft TAR September 26, 2016 EPA-HQ-OAR-2015-0827-0038 at pg. 4]~~

[607] Kargul, J., Stuhldreher, M., Barba, D., Schenk, C. et al., "Benchmarking a 2018 Toyota Camry 2.5-Liter Atkinson Cycle Engine with Cooled-EGR," SAE Technical Paper 2019-01-0249, 2019, doi:10.4271/2019-01-0249.

[608] NHTSA-2018-0067-12431, at 8.

diminishing efficiency returns." Similarly, BorgWarner commented that they "do not expect that variable compression ratio (VCR) or homogeneous charge compression ignition (HCCI) will see broad application in the short term, if ever. While each of these technologies can offer marginal efficiency gains at some engine speed-load conditions, the use of down-sized boosted engines with 8-10 speed transmissions makes it possible to run engines at near optimum conditions and effectively minimizes gains from VCR or HCCI. VCR mechanisms result in additional mass, cost and complexity, and true HCCI has yet to be demonstrated in a production vehicle. We do not believe that OEMs will judge these technologies to be cost effective."[609]

Finally, the agencies declined to incorporate some information and data for the NPRM or final rule central analysis for several reasons that are discussed in [Individual Technology Sections], below, but these reasons can be summarized as follows: much information or data produced by the agencies or submitted by commenters did not isolate the effectiveness impacts of individual technologies (or in some cases a combination of two or several technologies), but rather also included the benefits of additional unnamed technologies. Because the effectiveness improvement measured or claimed resulted from changes to more technologies than identified, the actual effectiveness of the technology or technologies is lower than the amount that can be realized in the real world. Accordingly, using the effectiveness value would lead to double counting effectiveness and undercounting costs as the unnamed technologies are added again as independent technologies in the rulemaking analysis. In many cases, this problem exists where data or information is based on laboratory testing or on-road testing of production vehicles or components including engines and transmissions. Production vehicles and components usually include multiple technology improvements from one redesign to the next, and rarely incorporate just a single technology change. Furthermore, technology improvements on production vehicles in some cases cannot be readily observed, such as the level of mechanical friction in an engine, and isolation and identification of the improvement attributable to each technology would be impractical given the costs and time required to do so. That said, in some cases, where possible to do so, the agencies used the data or information from production vehicles to corroborate information from the Autonomie simulations. However, the agencies declined to apply that data or information directly in the analysis if the effectiveness improvement attributable to a particular technology could not be isolated.

So, while previous analyses may have shown pathways to compliance with increasingly complex advanced gasoline engines, the NPRM and final rule analyses more appropriately reflect that the most complex gasoline engine technologies will account for a smaller share of manufacturers' products during the rulemaking timeframe. However, despite this fact, the NPRM and final rule analysis include *more* advanced powertrain technologies than previous analyses, in part to account for important considerations like intellectual property and the fact that some manufacturers have already started down the path of incorporating a certain advanced engine technology in their product portfolio, and that abrupt switching to another advanced engine technology would result in unrealistic stranding of capital costs. In addition, greater precision in how cumulative technologies applied to engines, as estimated through the Autonomie effectiveness modeling, appropriately reflects the diminishing returns to efficiency benefits that those advanced engines can provide. Moreover, as identified by a wide range of

[609] NHTSA-2018-0067-11895.

commenters, battery costs are projected to fall in the rulemaking timeframe to a point where, in the compliance modeling, it becomes more cost effective to add electrification technologies to vehicles than to apply other advanced gasoline engine technologies.

The agencies made these updates from prior analyses not, as some commenters have suggested, to "artificially overstate[] technology costs,"[610] or to "ignore[] the knowledge and expertise of the EPA engineering and compliance staff,"[611] "so that the model in many instances selects more expensive, less fuel efficient technology while excluding less expensive and more efficient alternatives,"[612] but because the updates reflected the agencies' reasonable assessment of the current state of vehicle technologies and their costs, and the state of future vehicle technologies and costs in the rulemaking timeframe.

Separate from the decision to update assumptions used for the NPRM analysis from prior analyses, the agencies did refine some technology effectiveness and cost assumptions from the NPRM to this final rule analysis. In addition to being appropriate for technical reasons, this should address some commenters' overarching concerns about understated technology effectiveness and overstated technology costs. For example, several commenters noted that the costs of BISG/CISG systems were higher for small Cars/SUVs and medium cars than for medium SUVs and pickup trucks, which the Alliance and FCA described as "implausible" and "misaligned with industry understanding," and which ICCT described as "contrary to basic engineering logic, which holds that a system which would be smaller and have lower energy and power requirements would be less expensive, not more."[613] The agencies agree, and have made changes to address this issue, as described in [Section Electrification].

After considering comments, the agencies also added several engine technologies and technology combinations for the final rule analysis. These included a basic high compression ratio Atkinson cycle engine, a variable compression ratio engine, a variable turbo geometry engine, and a variable turbo geometry with electric assist engine (VTGe). The NPRM discussed and provided engine maps for each of these technologies. The agencies also added new technology combinations including diesel engines with cylinder deactivation, turbocharged engines with advanced cylinder deactivation, diesel engines paired with manual transmissions, and diesel engines paired with 12-volt start-stop technology. Transmission revisions included updating the effectiveness of 6-speed automatic transmissions, applying updated shift logic for 10-speed automatic transmissions, and increasing the gear span for efficient 10-speed automatic transmissions. Mass reduction technology was expanded to include up to 20 percent curb weight reduction, compared to up to 10 percent for the NPRM. These changes, and the comments upon which they were made, are described in further detail in the following sections.

1. Engine paths

The internal combustion (IC) engine is a heat engine that converts chemical energy in a fuel into mechanical energy. Chemical energy of the fuel is first converted to thermal energy by

[610] NHTSA-2018-0067-11741.
[611] NHTSA-2018-0067-11741.
[612] NHTSA-2018-0067-12123.
[613] NHTSA-2018-0067-11741.

means of combustion or oxidation with air inside the engine. This thermal energy raises the temperature and pressure of the gases within the engine, and the high-pressure gas then expands against the internal mechanisms of the engine. This expansion is converted by the mechanical linkages of the engine to a rotating crankshaft, which is the output of the engine. The crankshaft, in turn, is connected to a transmission to transmit the rotating mechanical energy to the desired final use, particularly the propulsion of vehicles.

IC engines can be categorized in a number of different ways depending upon which technologies are designed into the engine: by type of ignition (e.g., spark ignition or compression ignition), by engine cycle (e.g., Otto cycle or Atkinson cycle), by valve actuation (e.g., overhead valve (OHV), single overhead camshaft (SOHC), or dual overhead camshaft (DOHC)), by basic design (e.g., reciprocating or rotary), by configuration and number of cylinders (e.g., inline four-cylinder (I4) or V-shaped six-cylinder (V6)), by air intake (e.g., forced induction (turbo or super charging) or naturally aspirated), by method of fuel delivery (e.g., port injection or direction injection), by fuel type (e.g., gasoline or diesel), by application (e.g., passenger car or light truck),or by type of cooling (e.g., air-cooled or water-cooled). For each combination of technologies among the various categories, there is a theoretical maximum efficiency for all engines within that set. There are various metrics that can be used to compare engine efficiency, and the four metrics we use or discuss in this preamble are:

- Brake specific fuel consumption (BSFC), which is the mass of fuel consumed per unit of work output (amount of fuel used to produce power);
- Brake thermal efficiency (BTE), which is the total fuel energy released per unit of work output (percentage of fuel used to produce power);
- Fuel consumption (gallons per mile), which looks at the gallons of fuel consumed per unit of work output (mile travelled); and
- Fuel economy (in MPG), which is the amount of work output (miles travelled) per unit (gallon) of fuel consumed.

When comparing the efficiency of IC engines, it is important to identify the metric(s) used and the test cycle for the measurement because results vary widely when engines operate over different test cycles. Two-cycle fuel economy tests used to certify vehicles' compliance with the CAFE standards tend to overestimate the average fuel economy motorists will typically achieve during on-road operation.[614] In the NPRM and for this final rule analysis, we considered technology effectiveness for the 2-cycle test procedures and AC and off-cycle test procedures to evaluate how technologies could be applied for manufacturers to comply with standards. We also considered real world operation beyond these test procedures when considering IC engine technologies in order to assure the technologies were configured and specified in a manner that could be used in real world vehicle applications.

[614] [2012 Rule FR 62988.]

a) Fuel Octane

In the NPRM, the agencies included a general overview of fuel octane (stability) level, including levels currently available, and the potential impact of fuel octane on engines developed for the U.S. market.[615] The agencies described that a typical, overarching goal of optimal spark-ignited engine design and operation is to maximize the greatest amount of energy from the fuel available, without manifesting detrimental impacts to the engine over expected operating conditions. Design factors, such as compression ratio, intake and exhaust value control specifications, and combustion chamber and piston characteristics, among others, are all impacted by the octane of the fuel consumers are anticipated to use.[616]

The agencies also discussed potential challenges associated with octane levels available currently, and how those octane levels may play a role in potential vehicle fuel efficiency improvements. Vehicle manufacturers typically develop their engines and engine control system calibrations based on the fuel available to consumers. In many cases, manufacturers may recommend a fuel grade for best performance and to prevent potential damage. In some cases, manufacturers may *require* a specific fuel grade for both best performance, to achieve advertised power ratings, and/or to prevent potential engine damage.

Consumers, though, may or may not choose to follow the manufacturer's recommendation or requirement for a specific fuel grade for their vehicle. As such, vehicle manufacturers often choose to employ engine control strategies for scenarios where the consumer uses a lower than recommended, or required, fuel octane level, as a way to mitigate potential engine damage over the life of a vehicle. These strategies limit the extent to which some efficiency improving engine technologies can be implemented, such as increased compression ratio and intake system and combustion chamber designs that increase burn rates and rate of in-cylinder pressure rise. If the minimum octane level available in the market were higher (especially the current sub-octane regular grade in the mountain states), vehicle manufacturers might not feel compelled to design vehicles sub-optimally to accommodate such blends.

When knock (also referred to as detonation) is encountered during engine operation, at the most basic level, non-turbo charged engines can adjust the timing of the spark that ignites the fuel, as well as the amounts of fuel injected at each intake stroke ("fueling"). In turbo-charged applications, knocking is typically controlled by adjusting boost levels along with spark timing and/or the amount of fuel injected. Past rulemakings discussed other techniques that may be employed to allow higher compression ratios, including optimizing spark timing, and adding of cooled exhaust gas recirculation (EGR). Regardless of the type of spark-ignition engine or technology employed, efforts to reduce or prevent knock with the lower-octane fuels that are available in the market result in the loss of potential power output, creating a "knock-limited" constraint on performance and efficiency.

[615] [CITE NPRM Discussion versus repeating here]

[616] In addition, PRIA Chapter 6 contains a brief discussion of fuel properties, octane levels used for engine simulation and in real-world testing, and how octane levels can impact performance under these test conditions.

The agencies noted that despite limits imposed by available fuel grades, manufacturers continue to make progress in extracting more power and efficiency from spark-ignited engines. Production engines are safely operating with regular 87 AKI fuel with compression ratios and boost levels once viewed as only possible with premium fuel. According to the Department of Energy, the average gasoline octane level has remained fundamentally flat starting in the early 1980's and decreased slightly starting in the early 2000s. During this time, however, the average compression ratio for the U.S. fleet has increased from 8.4 to 10.52, a more than 20 percent increase. As explained by the Department of Energy, "[t]here is some concern that in the future, auto manufacturers will reach the limit of technological increases in compression ratios without further increases in the octane of the fuel."[617] As such, manufacturers are still limited by the fuel grades available to consumers and the need to safeguard the durability of their products for all of the available fuels; thus, the potential improvement in the design of spark-ignition engines continues to be overshadowed by the fuel grades available to consumers.

EPA and NHTSA also described ongoing research and positions from automakers and advocacy groups on fuel octane levels, including comments received during past agency rulemakings and on the 2016 Draft TAR regarding the potential for increasing octane levels in the U.S. market. The agencies described arguments for adjusting to octane levels, including making today's premium grade the base grade of fuel available, which could enable low cost design changes to improve fuel economy and reduce tailpipe CO_2 emissions. Challenges associated with this approach include the increased cost to consumers who drive vehicles designed for current regular octane grade fuel, who would not benefit from the use of the higher cost higher-octane fuel. The costs of such a transition to higher-octane fuel would be high and persist well into the future, since unless current regular octane fuel were unavailable in the North American market, manufacturers would be effectively unable to redesign their engines to operate on higher-octane fuel. And the full benefits of such a transition would not be realized until vehicles with such redesigned engines were produced for a sufficient number of model years largely to replace the current on-road vehicle fleet. The transition to net positive benefits would take many years.

The agencies also described input received prior to proposal from renewable fuel industry stakeholders and from the automotive industry supporting high-octane gasoline fuel blends to enable fuel economy and CO_2 improving technologies such as higher compression ratio engines. Stakeholders suggested that mid-level (e.g., E30) high-octane ethanol blends should be considered and that EPA should consider requiring that mid-level blends be made available at service stations. Stakeholders supporting higher-octane blends suggested that higher-octane gasoline could provide auto manufacturers with more flexibility to meet more stringent standards by enabling opportunities for use of lower tailpipe CO_2 emitting technologies (e.g., higher compression ratio engines, improved turbocharging, optimized engine combustion). Further, EPA requested comment on whether and how EPA could require the production and use of higher octane gasoline consistent with Title II of the Clean Air Act.

[617] Fact of the Week, *Fact #940: August 29, 2016 Diverging Trends of Engine Compression Ratio and Gasoline Octane Rating*, U.S. Department of Energy, https://www.energy.gov/eere/vehicles/fact-940-august-29-2016-diverging-trends-engine-compression-ratio-and-gasoline-octane (last visited Mar. 21, 2018).

The agencies sought additional comment in the NPRM on various aspects of current fuel octane levels and how fuel octane could play a role in the future. More specifically, the agencies sought comment on how increasing fuel octane levels could have an impact on product offerings and engine technologies, as well as what improvements to fuel economy and tailpipe CO_2 emissions could result from higher-octane fuels. The agencies sought comment on an ideal octane level for mass-market consumption, and whether there were downsides with increasing the available octane levels and, potentially, eliminating lower-octane fuel blends. EPA also requested comment on whether and how EPA could require the production and use of higher-octane gasoline consistent with Title II of the Clean Air Act.

The agencies received numerous, wide-ranging comments in response to the NPRM discussion, and some direct responses to the agencies' requests for comments. The commenters included fuel producers, individual vehicle manufactures, environmental groups, vehicle suppliers, fuel advocacy groups, and agricultural organizations, among others. Commenters provided a broad range of comments ranging from explication of the many challenges to increasing available octane levels, to claims of the substantial efficiency increases that could be easily obtained by requiring higher-octane levels.

Several ethanol industry stakeholders commented in support of requiring higher-octane fuels using mid-level ethanol blends. The High-Octane, Low Carbon (HOLC) Alliance commented that it believes "NHTSA and EPA have a critical opportunity to cost-effectively ensure progress in fuel efficiency and CO_2 emissions standards. Scientific experts agree that high-octane, low-carbon fuel can yield greater fuel economy and emissions benefits when paired with internal combustion engines (ICEs). But, to realize such benefits, automobile manufacturers require approval sooner rather than later to such fuels. Alternatively, automobile manufacturers will be limited in their ability to maximize the environmental performance of their vehicles until non-liquid fuel engines become more readily available. In finalizing the Proposed Rule, the HOLC Alliance strongly urges EPA and NHTSA to establish a pathway forward toward incentivizing the production and adoption of higher-octane, lower carbon fuels. By doing so, EPA and NHTSA can continue to incrementally increase CO_2 and fuel economy standards, respectively."[618]

Renewable Fuels Associations (RFA) commented that "it strongly believes vehicles and fuels must be considered together as integrated systems. As EPA has recognized in the past, a 'systems approach enables emission reductions that are both technologically feasible and cost effective beyond what would be possible looking at vehicle and fuel standards in isolation.' Because ethanol-based high-octane low-carbon fuel blends would enable cost-effective gains in fuel economy and carbon dioxide reductions, the agencies should take steps to support [high-octane low-carbon] fuels in the final SAFE rule."[619]

RFA cited several studies indicating benefits are available from raising the floor of fuel octane levels currently available, and, particularly, "[t]he results from the studies reviewed

[618] HOLC Alliance, Detailed Comments, EPA-HQ-OAR-2018-0283-4196.
[619] RFA, Detailed Comments, EPA-HQ-OAR-2018-0283-4409.

generally support a main conclusion that splash blending ethanol is a highly effective means of raising the octane rating of gasoline and enabling low-cost efficiencies and reduced emissions in modern spark-ignition engines."[620] In addition, National Corn Growers Association stated that, "[w]ithout a change in fuel, automakers are reaching the limits on the efficiency gains that can be achieved with technology changes."[621]

The National Corn Growers Association, in conjunction with associated corn growing and agricultural groups, pointedly stated the EPA should, "[s]et a minimum fuel octane level of 98 RON and phase out low octane fuels as new optimized vehicles enter the market in MY 2023," and concluded that approving a "midlevel ethanol blend vehicle certification fuel would enable automakers to expedite design and testing of optimized vehicles for use with this new fuel."[622]

The 25x25 Alliance commented that "to meet the dual goals of greater fuel efficiency and reduced [CO_2] emissions, the utilization of higher compression spark ignition internal combustion engines will be essential. Increasing engine compression improves thermal efficiency. However, as compression increases, higher-octane fuels will be needed to prevent engine knock. Automakers and advocacy groups have expressed support for increases to fuel octane levels for the US market. Ethanol with its octane rating of 113 offers engine knock resistance at a lower cost than any other octane booster in gasoline. In addition, ethanol's lower direct and life-cycle [CO_2] emissions as compared to gasoline are well documented. For this reason, a fuel produced from a mixture of ethanol and gasoline and used in conjunction with advanced high compression engines presents itself as a technology pathway capable of complying with new CAFE/[CO_2] standards." They continue, "HOLC supporters recognize numerous barriers and other associated regulatory hurdles must be resolved before HOLC ethanol fuels are adopted at large scale… 25x25 believes it is imperative that the vehicle and fuel be treated as a comprehensive system. To date CAFE/[CO_2] standards have largely focused on vehicle engine technology. Advanced engine vehicles perform best in concert with fuels of suitable properties and composition to optimally enable and power them."[623]

The American Coalition for Ethanol (ACE) commented that "high-octane blends comprised of 25 to 30 percent ethanol would help bring down the cost for consumers compared to the premium-priced octane level advocated by oil refiners. Ethanol has a blending octane rating of nearly 113 and trades at a steep discount to gasoline. In many wholesale markets today, ethanol costs at least 60 cents per gallon less than gasoline. Ethanol delivers the highest octane at the lowest cost, allowing automakers to benefit by continuing to develop high-compression engine technologies and other product offerings to achieve efficiency improvements and reduced

[620] RFA, Detailed Comments, EPA-HQ-OAR-2018-0283-4409.
[621] National Corn Growers Association, https://www.ncga.com/file/1621/NCGA%20Comments%20Docket%20No.%20EPA-HQ-OAR-2018-0283%20and%20NHTSA-2018-0067.pdf.
[622] National Corn Growers Association, https://www.ncga.com/file/1621/NCGA%20Comments%20Docket%20No.%20EPA-HQ-OAR-2018-0283%20and%20NHTSA-2018-0067.pdf.
[623] 25x25 Alliance, Detailed Comments, EPA-HQ-OAR-2018-0283-4210.

emissions. The ideal way to transition from today's legacy fleet to new vehicles with advanced engine technologies designed to run optimally on a high-octane fuel is to utilize FFVs as bridge vehicles that can provide immediate demand for mid-level ethanol blends."[624]

Growth Energy commented that with a mid-level ethanol blend, automakers not only get higher-octane that they can use to optimize engines and gain further fuel efficiency, they will also see a fuel that has demonstrably lower carbon dioxide emissions.[625] The Illinois Corn Growers' Association et al., commented that "NHTSA and EPA must adapt the existing regulatory structure to reflect the specific characteristics of mid-level blend fuels. Working together, the ethanol industry, automakers, EPA and NHTSA can bring about, during the period covered by the SAFE program, a new generation of high efficiency internal combustion engines optimized to take advantage of this new fuel's unique properties."[626]

Ethanol industry commenters provided comment on several EPA actions they believe would be necessary to support higher-octane mid-level fuel blends:

- Set a minimum fuel octane level and phase out low-octane fuels as new optimized vehicles enter the market;
- Approve a high-octane, mid-level ethanol blend vehicle certification fuel;
- Correct the fuel economy formula by updating the R-Factor to be at or nearly "1" to reflect documented operation of modern engine technology;
- Extend a RVP waiver of 1 psi to all gasoline containing at least 10 percent ethanol;
- Adopt the Argonne National Laboratory GREET model to determine updated lifecycle carbon emissions for ethanol;
- Establish meaningful credits to automakers to incentivize transition to higher-octane fuel vehicles and continue to support flex-fuel vehicles; and
- Provide equal treatment to vehicle technologies that reduce carbon emissions.

The Clean Fuels Development Coalition, et al. suggested that, "the 'ideal octane level' to optimize LDV performance, fuel efficiency, and reduce harmful emissions and consumer costs is 98–100 RON produced with E30+ 'clean octane.'"[627] Concurrently, the HOLC Alliance and ACE, among others, also supported that 98 to 100 RON would be ideal octane levels for the nation.[628]

BorgWarner, a supplier to major automobile manufacturers, commented that "[f]uel octane is a limiting factor in the selection of compression ratio for all spark-ignition engines and the amount of boost for turbocharged engines. Higher-octane is particularly effective for using higher compression ratios with boosted engines," and stated that "[t]here is substantial merit to

[624] ACE, Detailed Comments, EPA-HQ-OAR-2018-0283-4033.
[625] Growth Energy, Detailed Comments, EPA–HQ–OAR–2010–0799- 9540-A2.
[626] Comment removed because it contains copyrighted data, Illinois Corn Growers Association, et al., https://www.regulations.gov/document?D=EPA-HQ-OAR-2018-0283-4198.
[627] Clean Fuels Development Coalition, et al., Detailed Comments, NHTSA-2018-0067-11988.
[628] HOLC Alliance, Detailed Comments, EPA-HQ-OAR-2018-0283-4196; ACE, Detailed Comments, EPA-HQ-OAR-2018-0283-4033.

raising the minimum octane required because current fuel pricing penalizes consumers for using higher-octane fuel. A base octane of 95 RON would be consistent with Europe. This would allow consistent development of engines for the broader US-EU market. Prior to the introduction of ethanol into gasoline, the base blend for regular fuel was typically 92 RON. Addition of 10% ethanol to this base blend gave 95 RON regular, so the base blend would be reformulated to retain the 92 RON at a lower cost. Returning to the previous base blend would be cost effective to the consumer."[629]

Auto manufacturers also provided comment on the topic of higher-octane fuels. The Alliance of Automobile Manufacturers (the Auto Alliance) commented that it "has long advocated for the availability of cost-effective, higher-octane fuel. The Alliance also believes the Agencies should require a transition to a higher minimum-octane gasoline (minimum 95–98 RON). There are several ways to produce higher-octane grade gasoline, such as expanding the ethanol availability, but the Alliance does not promote any sole or particular pathway."[630] The Alliance reiterated its position regarding fuel octane levels where, "[t]he Alliance has long supported two goals regarding the octane (anti-knock) properties of gasoline: 1) the availability of cost effective higher-octane fuels, greater than 95 Research Octane Number (RON) and 2) the immediate elimination of subgrade fuel less than 87 anti-knock index (AKI)." The Alliance also noted that "[t]he higher-octane fuel that is available today is sold as a premium grade. To support future engine technologies, the approach taken with today's premium fuel option would not be expected to provide an attractive value proposition to the customer; therefore, a new higher minimum-octane gasoline, 95–98 RON, is needed to achieve anticipated performance."

Ford Motor Company agreed with the Auto Alliance's collective comments on fuel octane level and added specific support to raising minimum octane levels, stating that "Ford concurs with those comments and supports increasing the marketplace octane rating in the U.S. to a minimum of 95 Research Octane Number (RON)." Ford also generally supported the agencies' fuel octane discussion in terms of impacts to vehicle performance, where "[h]igher octane gasoline enables opportunities for the use of key energy-efficient technologies, including: higher compression ratio engines, lighter and smaller engines, improved turbocharging, optimized engine combustion phasing/timing, and low temperature combustion strategies. All of these technologies paired with higher-octane gasoline permit smaller engines to meet the demands of the consumer while at the same time providing higher overall efficiencies."[631]

Volkswagen commented "[t]here may be several potential ways to achieve a high-octane fuel that may be more costly to the vehicle than others. Achieving an E10 high-octane fuel may mean a different hardware set than on E20 or E30 high-octane fuel. Elimination of sub-grades of market fuel (less than 87AKI) quickly is very important. If current 87 AKI and 85 AKI fuels remain in the market for backward compatibility (such as if an E30 were chosen as the high-octane fuel of the future), a robust method at the fuel dispensing station and incorporated into the fueling station equipment to prevent mis-fueling is necessary. However, an E10 high-octane

[629] BorgWarner, Detailed Comments, EPA-HQ-OAR-2018-0283-4174.
[630] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[631] Ford, Detailed Comments, EPA-HQ-OAR-2018-0283-5691.

pathway might have far fewer compatibility problems and might bring extra fuel economy to the drivers of those current vehicles."[632]

The agencies also received comments from the petroleum industry regarding higher-octane fuels. API commented that "[g]iven the multiple engine technology pathways available to the automakers for achieving future fuel economy and CO_2 emissions targets, the challenge of determining future market fuel gasoline octane number needs is complex and not yet settled. API believes that the octane number issue should be part of a comprehensive transport policy that addresses both vehicles and fuels as a system. API and its members are engaged in collaborations with the automakers and other stakeholders to better understand future fuel requirements for emerging powertrain technologies." API also commented "the future for gasoline octane number will be driven by the stringency of regulations that set future fuel economy and CO_2 requirements, the collective responses of the automakers to those regulations, consumer preferences regarding vehicles and fuels, and fuel supply economics. EPA's authority to regulate gasoline octane number is doubtful. Therefore, EPA should not attempt to regulate gasoline octane number at this time."[633]

In terms of challenges associated with potential high-octane fuel deployment, the American Fuel & Petrochemical Manufacturers (AFPM) commented that, "[a]side from a lack of legal authority, EPA faces numerous technical, logistical, and legal challenges and uncertainties in requiring the use of higher-octane fuels. Any such requirement would need a separate rulemaking dedicated to such a purpose with an extensive technical record in support, including test data on vehicles designed for the higher-octane fuel and on the existing fleet with and without higher-octane."[634]

AFPM also commented that it does not support the potential regulatory requirement for the production or use of higher octane gasoline as a compliance option. AFPM commented that EPA lacks the authority to require the use of higher octane fuels under CAA § 211(c)(1)(A). AFPM further commented "[t]he only vehicles legally permitted to use more than 15 percent ethanol blends are flex-fuel vehicles, which are currently certified to utilize both E10 and E85. Without an alternative certification for an auto manufacturer to build an E30 certified vehicle, which would require extensive testing and certification procedures as well as sufficient market availability of the certification fuel, it would be inappropriate for the Administration to consider such vehicles as a viable option in the 2022-2026 compliance period."

Gasoline retailers also commented regarding higher-octane fuels. NACS and SIGMA commented that they support examining the use of such fuels as a potential path towards future emissions reductions and that it will be important that the agencies appropriately consider and address a variety of related issues, including:

1. How to allow and handle the expanded sales of higher-octane fuels, which may include fuels that currently face barriers to sale, such as E15;

[632] Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[633] API, Detailed Comments, EPA-HQ-OAR-2018-0283-5458.
[634] AFPM, Detailed Comments, EPA-HQ-OAR-2018-0283-5698.

2. Streamlining the registration and regulation of higher-level blends of ethanol;
3. Addressing misfueling liability concerns of retailers;
4. Streamlining federal labeling requirements and ensuring federal preemption of state requirements; and
5. Addressing any other regulatory and legislative challenges associated with the use of higher-octane fuels.[635]

NATSO commented that "the Agencies should under no circumstances consider 'requiring that mid-level [ethanol] blends be made available at service stations'" and went on to say that "retailers would need to be assured that they will not be held responsible for customers that misfuel… Federal dispenser labeling requirements would have to be streamlined and state requirements would have to be preempted.… Auto manufacturers would have to warrant all new higher-octane vehicles up to at least E15 depending upon vehicles' capabilities, and would have to affirmatively state which cars in the existing fleet can run on E15 and ensure that the cars are warrantied or retroactively warrantied as such."[636]

UCS commented that "[a]n orderly transition to high-octane fuel would take several years to complete. It will take time for the necessary regulations to be finalized, for vehicles optimized for high-octane gasoline to come to market and to build out the fuel distribution infrastructure to make this fuel broadly available. And even once high-octane gasoline is in use, it will take more time for automakers to phase-in new models optimized for high-octane fuel and to fully replace the legacy E10 fleet. Another factor to consider is that the rising share of high-octane gasoline will be buffered by falling sales of gasoline, given increasing fuel efficiency, such that the overall demand for ethanol will change more slowly. Our expectation is that high-octane gasoline will not significantly enter commerce before 2026, and subsequently will only gradually gain market share through 2040. There is no realistic prospect of completing this process before 2025 or 2026, the timeframe of this rulemaking. The appropriate context for this discussion within vehicle rules is the next round of fuel economy and emission standards. Even then, an expeditious rulemaking process will be required to achieve adequate regulatory clarity to facilitate rapid adoption post-2026." UCS also commented "[we] strongly oppose granting fuel economy credits based on the technical potential of vehicles to operate on high-octane fuel before there is clear evidence that high-octane fuel is in use and the potential fuel economy benefits are being realized on the road."[637]

The agencies have reviewed the submissions received in response to their solicitation of comments concerning fuel octane levels and recognize the potential that higher-octane fuels, coupled with advanced engine technologies, can provide for improvements to fuel economy and tailpipe CO_2 emissions. The agencies agree with commenters that establishing a higher minimum octane for gasoline is a complex undertaking that would require consideration of a wide array of difficult issues. In light of the complexity of the constellation of issues, the fact that EPA did not propose new octane requirements, and that EPA's authority to set fuel requirements resides in CAA section 211(c)(1), the agencies recognize that the present

[635] Joint submission on behalf of NACS and SIGMA, Detailed Comments, EPA-HQ-OAR-2018-0283-5824.
[636] NATSO, Detailed Comment, EPA-HQ-OAR-2018-0283-5484.
[637] UCS, Detailed Comments, NHTSA-2018-0067-12039.

rulemaking is not the appropriate vehicle to set octane levels. If EPA pursues future rulemaking action on this topic, it would consider these comments in that context and in consideration of the appropriate statutory provisions. The agencies note that the current vehicle certification process provides a path to certify a vehicle requiring the use of high-octane fuel, which allows the impact of such fuels to be captured over the required certification test cycles for CO_2 emissions and fuel economy.

EPA also is declining to adopt new incentives for flex-fueled vehicles (FFVs) (vehicles designed to operate on gasoline or E85 or a mixture), as some commenters suggested. FFV incentives were not identified by EPA in its request for comments in the proposed rule and are outside the scope of this rulemaking. ~~In addition, EPA notes that it is not adopting additional incentives for other technologies such as EVs, hybrids, and natural gas vehicles as part of the SAFE vehicle rulemaking, as discussed above.~~

b) Engine Maps

Engine paths include numerous engine technologies that manufacturers can use to improve fuel economy and reduce CO_2. Some engine technologies can be incorporated into existing engine design architectures with minor or moderate changes to the engine, but many engine technologies require an entirely new engine architecture or a major refresh. For this final rule analysis 23, unique engine technologies are available for adoption, and are evaluated uniquely across the ten separate vehicle types (technology classes).

For the NPRM and final rule analysis, the impact of engine technologies on fuel consumption, torque, and other metrics was characterized using GT-POWER© modeling conducted by IAV Automotive Engineering, Inc. (IAV). IAV is one of the world's leading automotive industry engineering service partners and has extensive experience in testing and modeling engines and combustion. GT-POWER is a commercially available engine modeling tool with detailed cylinder and combustion modeling capabilities.[638] GT-POWER is used to simulate engine behavior and provides data on engine metrics, including: power, torque, airflow, volumetric efficiency, fuel consumption, turbocharger performance, and other parameters. The primary outputs of IAV's use of GT-POWER for this analysis are the development of engine maps that provide operating characteristics of engines equipped with specific technologies.

When an engine is running, at any given point in time, the operation can be characterized by the engine's crankshaft rotational speed (typically in revolutions per minute, or RPM) and engine output (torque) level. Engines can operate at a range of engine speed and torque levels. Engine maps provide a visual representation of various engine performance characteristics at each engine speed and torque combination across the operating range of the engine. A common example of a performance characteristic is BSFC.[639] Other characteristics include engine emissions, engine efficiency, and engine power.

[638] More information regarding GT Power Modeling is available at https://www.gtisoft.com/gt-suite-applications/propulsion-systems/gt-power-engine-simulation-software.
[639] The amount of fuel needed to achieve a specific power, or how efficiently an engine uses fuel to produce work.

Engine maps have the appearance of topographical maps, typically with engine speed on the horizontal axis and engine torque on the vertical axis. A third engine characteristic, BSFC, is displayed as contours, defining the operating regions for that BSFC with each contour showing all operating points at a specified BSFC value. Once created, the data they contain is referenced for engine fuel consumption at a given engine speed and torque operating point.

For the NPRM and final rule analysis, the agencies relied on IAV to develop engine maps representing each of the engine technologies. IAV used benchmark production engine test data, component test data, and manufacturers and suppliers' technical publications to develop a one-dimensional GT-POWER engine model for the baseline engine technology configuration. Technologies were incrementally added to the baseline model to assess their impact on fuel consumption. IAV used its global engine database that includes benchmarking data, engine test data, single cylinder test data, prior modeling studies, and technical publications and information presented at conferences to populate the assumptions and inputs used for engine map modeling, and to validate the ultimate results.[640] ANL used the engine maps resulting from this analysis as inputs for the Autonomie full vehicle simulation modeling.

As described in the NPRM and PRIA, the agencies developed engine maps for technologies that are in production today or that are expected to be available in the rulemaking timeframe. The agencies recognize that engines with the same combination of technologies produced by different manufacturers will have differences in BSFC and other performance measures,[641] due to differences in the design of engine hardware (*e.g.*, intake runners and head ports, valves, combustion chambers, piston profile, compression ratios, exhaust runners and ports, turbochargers, etc.), control software, and emission calibration. Therefore, the engine maps are intended to represent the levels of performance that can be achieved on average across the industry in the rulemaking timeframe.

Accordingly, the agencies noted that it was expected that the engine maps developed for this analysis will differ from engine maps for manufacturers' specific engines. For a given engine configuration, some production engines may be less efficient and some may be more efficient than the engine maps presented in the analysis. However, the agencies intended and expected that the incremental changes in performance modeled for this analysis, due to changes in technologies or technology combinations, will be similar to the incremental changes in performance observed in manufacturers' engines for the same changes in technologies or technology combinations. Most importantly, using a single engine model as a reference provides a common base for comparison of all incremental changes resulting from technology changes, and anchors incremental technology effectiveness values to a common reference. The effectiveness values from the internal simulation results were validated against detailed engine

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[640] GT-Power technical publications for numerous technology assessment. Available at https://www.gtisoft.com/publicationresult/?authors_ids%5B0%5D&type&category_ids%5B0%5D=340&companies%5B0%5D&industry_ids%5B0%5D=365&years%5B0%5D=2018&years%5B1%5D=2017&years%5B2%5D=2016&years%5B3%5D=2015&years%5B4%5D=2014&years%5B5%5D=2013&phrase&pagination=1&submit=submit&numperpage=-1. Last accessed September 18, 2019.

[641] [Cite Autonomie Model Documentation].

maps produced from engine benchmarking programs, as well as published information from industry and academia, ensuring reasonable representation of simulated engine technologies.[642]

As discussed in the NPRM, the agencies updated the list of engine technologies, before and after the Draft TAR, based on stakeholder comments and consultations with CARB, ANL, and IAV. The technology list was built on the technologies that were considered in the 2012 final rule, and included technologies that are being implemented or that are under development and feasible for production in the rulemaking timeframe. The agencies noted that some advanced engines were included in the simulation that were, and often still are, not yet in production, and the engine maps for those engines were either based on CB1 or theoretical data. The agencies also stated in the NPRM that the final rule analysis may include updated engine maps for existing modeled engines, or entirely new maps added to the analysis if either action could improve the quality of the fleet-wide analysis.

While there are a large number of possible combinations of engine technologies, the agencies categorized the IAV engine maps used in the NPRM full vehicle simulations into six categories. The categories were based on engine architecture and include: dual overhead camshaft (DOHC) engines, single overhead camshaft (SOHC) engines, turbocharged engines, hybrid Atkinson cycle engines,[643] non-hybrid Atkinson mode engines, and diesel engines. Another unique technology that was available for adoption for the NPRM analysis was the advanced cylinder deactivation (ADEAC) for the SOHC and DOHC engines, however this technology was modeled using a fixed effectiveness value rather than an engine map, because the agencies did not have sufficient data to be used as input to the engine map or full vehicle simulation modeling. In addition, the agencies provided potential engine maps and additional specifications for several other technologies that could be considered for the final rule analysis. These included a basic high compression ratio Atkinson mode engine, a Miller cycle engine, and an engine with an electric assist.

The full list of engine maps used in the NPRM is presented in Table VI-21Table VI-21below.

Table VI-21 - Engine Maps Used for NPRM Analysis

Engines	Technologies	Notes	Engine Reference Peak Power (kW)
Eng01	DOHC VVT	Parent NA engine, Gasoline, 2.0L, 4 cyl, NA, PFI, DOHC, dual cam VVT, CR10.2	108
Eng02	DOHC VVT+VVL	VVL added to Eng01	108
Eng03	DOHC VVT+VVL+SGDI	SGDI added to Eng02, CR11	113

[642] [Cite IAV combustion stability presentations between engine model and engine data].
[643] These types of Atkinson cycle engines are mainly for hybrid applications like Toyota Prius or Ford C-Max.

Eng04	DOHC VVT+VVL+SGDI+DEAC	Cylinder deactivation added to Eng03	113
Eng5a	SOHC VVT+PFI	Eng01 converted to SOHC (gasoline, 2.0L, 4cyl, NA, PFI, single cam VVT)	Reference only
Eng5b	SOHC VVT (level 1 Red. Friction)	Eng5a with valvetrain friction reduction (small friction reduction)	109
Eng6a	SOHC VVT+VVL (level 1 Red. Friction)	Eng02 with valvetrain friction reduction (small friction reduction)	109
Eng7a	SOHC VVT+VVL+SGDI (level 1 Red. Friction)	Eng03 with valvetrain friction reduction (small friction reduction), addition of VVL and SGDI	114
Eng8a	SOHC VVT+VVL+SGDI+DEAC (level 1 Red. Friction)	Eng04 with valvetrain friction reduction (small friction reduction), addition of DEAC	114
Eng12	DOHC Turbo 1.6l 18bar	Parent Turbocharged Engine, Gasoline, 1.6L, 4 cyl, turbocharged, SGDI, DOHC, dual cam VVT, VVL	132
Eng13	DOHC Turbo 1.2l 24bar	Eng12 downsized to 1.2L	133
Eng14	DOHC Turbo 1.2l 24bar + Cooled EGR	Cooled external EGR added to Eng13	133
Eng17	Diesel	Diesel, 2.2L (measured on test bed)	141
Eng18	DOHC VVT + SGDI	Gasoline, 2.0L, 4 cyl, NA, SGDI, DOHC, VVT	113
Eng19	DOHC VVT + DEAC	Cylinder deactivation added to Eng01	113
Eng20	DOHC VVT + VVL + DEAC	Cylinder deactivation added to Eng02	113
Eng21	DOHC VVT + SGDI + DEAC	Cylinder deactivation added to Eng18	113
Eng24	Current SkyActiv 2.0l 93AKI	Non-HEV Atkinson mode, Gasoline, 2.0L, 4 cyl, DOHC, NA, SGDI, VVT, CR 13.1, 93 AKI	101
Eng25	Future SkyActiv 2.0l CEGR 93AKI+DEAC	Non-HEV Atkinson mode, Gasoline, 2.0L, 4 cyl, DOHC, NA, SGDI, VVT, cEGR, DEAC CR 14.1, 93 AKI	101
Eng26	Atkinson Cycle Engine	HEV and PHEV Atkinson Cycle Engine Map 1.8L	73

[Table forthcoming]

Comments on engine maps varied, with industry commenters generally supporting the maps used in the NPRM analysis and CARB and environmental advocate commenters generally objecting to the maps. The Alliance argued that previously-modeled fuel efficiency

improvements for downsized, turbocharged engine technologies were "highly optimistic," and stated that the updated engine maps used for the NPRM analysis were an improvement.

ICCT, in contrast, ~~cited draft deliberative comments from some EPA staff members that were docketed pursuant to CAA Section [xx]307(d) to~~ argued that the IAV engine maps used for the NPRM analysis were out of date, and better engine maps benchmarked by EPA staff ~~using EPA's ALPHA model~~ were available and should have been used instead.[644] UCS similarly stated that ANL work used for previous CAFE technical documents had relied on outdated engine maps, and that the new IAV engine maps used in this rulemaking were developed for a different purpose and have not been benchmarked against the latest engines either on the road or in development.[645] ICCT questioned whether the agencies had validated engines 13 and 14 with physical testing and/or simulation modeling to the level of quality of EPA's simulation modeling.[646] ICCT further asserted that EPA's benchmarked engine maps had been "knowingly disregarded" for the NPRM analysis, and stated that the NPRM analysis was therefore arbitrary.[647] ICCT commented that the agencies must conduct and disclose a systematic investigation and comparison of engine benchmarking, engine modeling, and transmission modeling completed by EPA, Ricardo, and ANL for model year 2014-2018 vehicles. ICCT recommended that the agencies rely on engine maps used for past EPA ALPHA modeling while the agencies conduct such an investigation.

Commented [A219]: DELETE: Unnecessary so delete.

Commented [A220]: CHANGE AS SHOWN: ALPHA is not used to benchmark engines.

The agencies believe it is most important for engine map data to provide accurate BSFC information for known technologies and technology levels. The timeframe for the testing or modeling is unimportant, because time by itself doesn't impact engine map data. A given engine or model will produce the same BSFC map regardless of when testing or modeling is conducted. Simplistic discounting of engine maps based on temporal considerations alone could result in discarding useful technical information. For example, the engines on some MY 2017 vehicles in the analysis fleet have technologies that were initially introduced ten or more years ago. Accordingly, having engine maps that are representative of those technologies is important for the analysis. The most basic engine technology levels also provide a useful baseline for the incremental improvements for other engine technologies. Also, the narrow use of temporal considerations would also result in the discarding of a number of engine maps from Ricardo that were used for the EPA Draft TAR and Proposed Determination analyses.[648] Therefore, agencies do not agree with commenter assertions that the engine maps are be out of date.

Commented [A221]: REVISE: None of the commenters are arguing that "time by itself" affects engine data. I assume this is in response to comments pointing out that the IAV engine maps are out of date, in which case the reply is not responsive to the comment.

Commented [A222]: REVISE: This response misunderstands the comment being responded to. The "outdated engine map" comment being responded to refers to the fact that the map itself is based on technology that has nearly disappeared from the fleet, and so is not applicable to modeling current or future engines. The comment does *not* refer to the year the engine maps were created.

The same commenters also appear to misunderstand how the agencies' effectiveness data, including engine maps, were used in the NPRM analysis (and in past rulemakings). The analysis never applies *absolute* BSFC levels from the engine maps to any vehicle model or configuration

[644] International Council on Clean Transportation, Attachment 3, Docket No. NHTSA-2018-0067-11741, at 1-49 (citing EPA docket ID for CAA docketed material). EPA had commented that the IAV maps were out of date at the time of the 2016 Draft TAR, "further strengthening our conclusions that the engine maps used in the CAFE analysis are not representative of what the industry is currently producing and will be producing in the 2020-2030 time frame assessed in the CAFE model."

[645] Union of Concerned Scientists, Technical Appendix, Docket No. NHTSA-2018-0067-12039, at p. 4.

[646] International Council on Clean Transportation, Attachment 3, Docket No. NHTSA-2018-0067-11741, at 1-46.

[648] [Reference Ricardo work from 2010 EPA 2010 report].

for the rulemaking analysis. The *absolute* fuel economy values from the full vehicle Autonomie simulations are used only to determine *incremental* effectiveness for switching from one technology to another technology. The *incremental* effectiveness is applied to the absolute fuel economy of vehicles in the analysis fleet, which are based on CAFE compliance data. For subsequent technology changes, incremental effectiveness is applied to the absolute fuel economy level of the previous technology configuration. Therefore, for a technically sound analysis, it is most important that the *differences in BSFC among the engine maps* be accurate, and not the absolute values of the individual engine maps. However, achieving this can be challenging.

A technically sound approach is to use a single or very small number of baseline engine configurations with well-defined BSFC maps, and then, in a very systematic and controlled process, add specific well-defined technologies and create a BSFC map for each unique technology combination. This could theoretically be done through engine or vehicle testing, but testing would need to be conducted on a single engine, and each configuration would require physical parts and associated engine calibrations to assess the impact of each technology configuration, which is impractical for the rulemaking analysis because of the extensive design, prototype part fabrication, development, and laboratory resources that are required to evaluate each unique configuration. Modeling is an approach used by industry to assess an array of technologies with more limited testing. Modeling offers the opportunity to isolate the effects of individual technologies by using a single or small number of baseline engine configurations and incrementally adding technologies to those baseline configurations. This provides a consistent reference point for the BSFC maps for each technology and for combinations of technologies which enables the differences in effectiveness among technologies to be carefully identified and quantified. The agencies selected this approach for the NPRM and final rule. Engine maps were created by IAV using this technically sound and rigorous methodology. Both absolute engine maps and the incremental differences in engine maps were presented in the PRIA.

Using a mix of certain engine maps from engine modeling and others from benchmarking data provides no common reference for measuring impacts of adding specific technological improvements. In addition, as discussed in further detail in [Section XXX], manufacturers often implement multiple fuel-saving technologies simultaneously when redesigning a vehicle and it is not possible to isolate the effect of individual technologies by using laboratory measurements of a single production engine or vehicle with a combination of technologies. Because so many vehicle and engine changes are involved, it is not possible to attribute effectiveness improvements accurately for benchmarked engines to specific technology changes. This leads to overcounting or undercounting technology effectiveness.

Further, while two or more different manufacturers may produce engines with the same high level technologies (such as a DOHC engine with VVT and SGDI), each manufacturer's engine will have unique component designs that cause its version of the engine to have a unique engine map. For example, engines with the same high level technologies have unique intake manifold and exhaust manifold runners, cylinder head ports and combustion chamber geometry that impact charge motion, combustion and efficiency, as well as unique valve control, compression ratios, engine friction, cooling systems, and fuel injector spray characteristics, among other factors. The agencies developed and used a single engine map to represent each

technology and each combination of engine technologies. ~~Therefore, it should not be expected that any of the agencies' engine maps would necessarily precisely align with a specific manufacturer's engine, unless of course the engine map was developed from that specific engine.~~ The agencies ~~do not~~ agree with ICCT that comparing an engine map used for the rulemaking analysis to a single specific benchmarked engine ~~has technical relevance, beyond~~ serv~~inges~~ as a general corroboration for engine maps. Differences are also explained by the NPRM and final rule analyses using large-scale full vehicle Autonomie simulations to estimate effectiveness instead of rough LPM approximations based on limited ALPHA simulation work. These issues are discussed in more detail in Section [Tech Effectiveness and Modeling]. The agencies also do not agree with ICCT that Eng13 and Eng14 should be validated by conducting full vehicle modeling and comparing the results with a single benchmarked vehicle. In addition to the issues associated with engines discussed above, full vehicle benchmarking captures effectiveness, of not only the engine, but of all of the other fuel economy improving technologies on a vehicle, such as transmission efficiency, improved accessories, and mass reduction. The issues discussed above are further compounded by the fact that many more technologies impact vehicle testing, such as accessory loads and test vehicle to test vehicle variability.

Commented [A223]: DELETE: This statement is problematic from the standpoint of defending the Autonomie work. Of course the definition of "precisely" could be debated, but any engine maps representing existing engine technologies should be expected to be very similar to the maps of existing engines.

Commented [A224]: CHANGE AS SHOWN: This appears to be in response to ICCT's comment asking for comparisons between modeled and tested engines. I'm pretty sure ICCT is asking for "general corroboration for engine maps," so I'm not sure what part of that the agencies disagree with.

Accordingly, the agencies declined directly to use the Ricardo and other EPA engine maps created from engine benchmarking as inputs for this rulemaking because, among other reasons discussed below, they did not afford the opportunity to evaluate the effectiveness improvements for specific, individual technologies. For example, the 2018 Toyota Camry 2.5L engine that EPA benchmarked had a broad array of observable technologies, and several more that were not observable.[649] However, there was no baseline from which to isolate or compare any of the *individual* technology improvements. For example, Toyota commented on this benchmarking, stating:

> Past Toyota comments on Atkinson-cycle benefits have addressed only those derived from variable valve timing (VVT) with late intake valve closing (LIVC) that enables a 13:1 compression ratio. The total 18.6 percent improvement of the 2018 Camry 2.5L over the previous generation also includes benefits from cEGR and internal engine design changes such as to the block, cylinder head, pistons, valvetrain, as well as drivetrain and body/chassis enhancements.[650]

These comments highlighted and clarified that the efficiency improvements in this engine were driven by several additional technological improvements~~, and not merely the Atkinson and higher compression ratio design that was assumed for the EPA Draft TAR and Proposed Determination analyses~~.

Commented [A225]: DELETE: This statement is factually incorrect. Everyone knows that each engine contains a package of technologies, and relative efficiency is a function of the entire suite of technologies and their implementation. This is, in fact, a strength of using benchmarking data – there is no estimation or modeling of technologie interactions, there is just measurement.

NHTSA and ANL may have thought the only differences between the Toyota engine and other engines were high compression ratio and Atkinson timing, but that was not what EPA assumed in the Draft TAR.

However, the agencies agree that component, engine and vehicle test data are very important for validating simulation systems, such as Autonomie, and for validating model inputs, like engine maps. Accordingly, the agencies *did* fully consider engine maps used in prior

[649] EPA Test Data. 2018 Toyota Camry 2.5L A25A-FKS Engine Tier 3 Fuel. Available at https://www.epa.gov/sites/production/files/2019-04/2018-toyota-2.5l-a25a-fks-engine-tier3-fuel-test-data-package-dated-04-08-19.zip. Last accessed Nov. 20, 2019.

[650] NHTSA-2018-0067-12431. Supplemental Comments – Toyota Motor North America, at p. 1-2.

rulemakings, along with a broad array of other data as part of the process for evaluating the IAV engine maps that were used for the NPRM and the final rule simulation work. Engine maps from Ricardo, EPA benchmarking, NHTSA-sponsored benchmarking,[651] information from technical papers and conferences,[652] extensive data and expertise from the ANL AMTL vehicle testing group and Energy modeling group, [653] and the 2015 NAS report,[654] were all sources used to confirm that incremental technology effectiveness estimates were appropriate. The engine maps developed by IAV ~~using the more rigorous and technically sound approach~~ provided ~~more accurate~~reasonable estimates for the incremental impacts of engine technologies. Using this ~~more rigorous~~ approach explains some of the effectiveness and cost differences between the NPRM and final rule analyses and the EPA Draft TAR and Proposed Determination analyses.

Commented [A226]: CHANGE AS SHOWN: There's nothing fundamentally wrong with using incrementally constructed engine maps. However, it relies heavily on modeling, which can make it difficult to account for manufacturer constraints, and requires some sort of reality check to ensure modeled predictions match real data. Calling this approach "more rigorous and technically sound" is unsupported and untrue.

Next, Roush Industries ("Roush"), writing on behalf of the California Air Resources Board, commented that the NPRM-modeled engines vary in cylinder size, which would significantly alter combustion, heat transfer, knock tolerance, and other important operating parameters.[655] Roush stated that a more accurate simulation, which would improve incremental fuel economy improvement, should maintain a consistent cylinder displacement (500cc) and vary the number of cylinders or expected fuel consumption maps.[656]

The agencies believe that holding cylinder volume constant is the appropriate approach to research seeking to identify the impacts of technological changes on BSFC, torque, power, and other characteristics, when holding cylinder volume constant. However, as explained in Section [Maintaining vehicle attributes] and Section [Performance Neutrality], CAFE and CO_2 rulemaking analyses attempt to maintain vehicle attributes, including performance, and hold all of the attributes constant when showing pathways that improve fuel economy. Therefore, the agencies' analyses require engine maps that attempt to hold *performance* constant—not necessarily cylinder size. Since certain fuel economy improving technologies would *increase* performance if cylinder size is held constant, such as when adding turbocharging technology, the agencies appropriately include changes in displacement and cylinder volume for technologies that have a significant impact on engine torque and power, such as turbocharging. For a number of fuel economy improving technologies that had smaller impacts on engine torque and power, the engine maps were created with cylinder volume held constant. Table VI-21Table VI-21 identifies the engine displacement information for each of the engine maps. For example, the same engine displacement (2.0 L) and cylinder displacement (500 cc) was used for creating engine maps for naturally aspirated engines Eng01, Eng02, Eng03, Eng04, Eng05a, Eng5b, Eng06a, Eng07a, and Eng08a, whereas engine displacement (1.6 L) and cylinder displacement (400 cc) is used for creating the engine map for turbocharged engine Eng12 in order to maintain performance. The agencies have concluded that the approach used for the NPRM and the final

[651] [F150 NHTSA benchmarking].

[653] [Reference AMTL and Energy Group here].

[654] National Research Council. 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, DC - The National Academies Press, at pp. 294-305. https://doi.org/10.17226/21744.

[655] [Roush at p.x]

[656] Roush Industries on behalf of California Air Resources Board, Rogers_Final_Final_NPRM_10.26.2018, Docket No. NHTSA-2018-0067-11984, at p.12.

rule analysis is the most technically sound approach given the data needs and assessments required for CAFE and CO_2 rulemaking.

Roush also commented as follows:

> [S]everal of the base engine maps used in the 2018 PRIA analysis exhibit maximum thermal efficiency (lowest fuel consumption) at 2000-3000 rpm and at maximum load, which is unrealistic for normal passenger vehicle engines. Such maps will over predict fuel economy for extremely down-sized applications (very small engine in a heavy vehicle). This is because there is no fuel economy penalty for running the engine at a high loads point where, in reality, BSFC is high due to retarding spark timing to prevent knocking and fuel enrichment to reduce exhaust temperatures to protect exhaust valves and turbocharger components.[657]

For example, Roush stated that Eng12 is predicted to have its highest efficiency at very high load and high engine speeds with no degradation in brake specific fuel consumption (BSFC) at engine speeds between 2,000 rpm and 4,500 rpm all the way up to peak load, which is unrealistic because turbocharged engines at high loads require retarded spark timing to prevent knock and fuel enrichment to prevent overheating of the turbocharger and related components.[658] Roush stated that these factors would increase fuel consumption and reduce efficiency under real-world conditions.[659] Roush also stated that another effect of the Eng12 fuel consumption curve would be to predict unreasonably good fuel consumption at very high power levels for downsized turbocharged engines. Roush stated this could bias technology pathways in over-predicting fuel economy benefits for small engines installed in heavier vehicles, causing an overly optimistic predicted performance of the vehicle with regard to drivability, acceleration, and fuel consumption, which would create unrealistic real-world pathways to compliance.[660]

As discussed in the [ANL full vehicle model] documentation, the simulations for the NPRM and final rule analyses were conducted using 2-cycle test procedures, because they are the test procedures used for CAFE and CO_2 compliance.[661] Therefore, the engines maps are intended to represent BSFC accurately under those test conditions. During 2-cycle test conditions, engines do not operate for extended periods at the speed and high load conditions noted by Roush—which are not relevant to these test procedures. A few vehicle and engine combinations may operate at those speed and load points only briefly during the 2-cycle CAFE and CO_2 tests. Engines are capable of operating for short periods of time under higher exhaust temperature conditions and manufacturers commonly delay fuel enrichment until it is needed to protect engine components (in particular exhaust valves and exhaust manifolds) from excessive

Commented [A227]: REVISE: This is not incorrect; however, it represents an inconsistant position. Either the onset of knock and resultant (real!) timing changes are important (in which case these engine maps ought to be corrected) or the onset of knock and resultant timing changes are NOT important (in which case there needn't be any changes due to octane / knock onset differences between Tier 2 and Tier 3).

[657] Roush Industries on behalf of California Air Resources Board, Rogers_Final_Final_NPRM_10.26.2018, Docket No. NHTSA-2018-0067-11984, at p.[x].
[658] Roush Industries on behalf of California Air Resources Board, Rogers_Final_Final_NPRM_10.26.2018, Docket No. NHTSA-2018-0067-11984, at [x].
[659] Roush Industries on behalf of California Air Resources Board, Rogers_Final_Final_NPRM_10.26.2018, Docket No. NHTSA-2018-0067-11984, at [x].
[660] Roush Industries on behalf of California Air Resources Board, Rogers_Final_Final_NPRM_10.26.2018, Docket No. NHTSA-2018-0067-11984, at [x].
[661] [ANL Full Vehicle Modeling Documentation reference]

temperatures that can impact engine durability. Fuel enrichment can be delayed because, similar to cooking food, it takes a period of time at higher temperature for components to heat up and reach a temperature that would impact durability. Because these high speed and load conditions occur for a relatively short time during the CAFE and CO_2 test cycles, and then return to lower speed and/or load conditions with lower exhaust temperature, engines operate for the entire CAFE and CO_2 test cycles without triggering fuel enrichment. The fuel enrichment delay also enables vehicles to comply with criteria emission regulations and improves real world fuel economy. Therefore, the engine maps used for the NPRM and final rule analysis fully represent how engines operate during CAFE and CO_2 test cycles, and properly do not include fuel enrichment at all 2-cycle operating conditions. Also, a trained knock model was used to develop the engine maps, and the spark timing reflects appropriate levels for engine operation during the delay in fuel enrichment.

Next, regarding developing the NPRM engine maps to account for Tier 3 test fuel, the Alliance and Ford stated that the engine maps using Tier 3 test fuel represented an improvement over prior analyses. The Alliance stated that previous EPA modeling had incorrectly used Tier 2 premium octane fuel to predict the benefits of engine technologies, which overstated fuel economy gains that would be achievable when using regular-grade octane Tier 3 fuel. Ford provided similar comments, and also noted that regular grade octane fuel will be required for compliance after the 2020 model year.[662]

In contrast, ICCT and UCS both commented that the agencies had incorrectly updated the IAV engine maps developed with Tier 2 test fuel to account for Tier 3 fuel.[663] ICCT stated that the update unjustifiably and artificially reduced the effectiveness of the turbo technologies and suggested that the fuel update adjustment should not have been done at all, stating that manufacturers that label vehicles as "premium fuel required" are required to show no emissions changes over all test cycles when using regular octane fuel and therefore reducing effectiveness for fuel differences as the agencies did with the IAV engine maps is unrealistic and inappropriate.

Commented [A228]: REVISE: The opposite is true. Manufacturers that do NOT label vehicles as "premium fuel required" are required to show this. Why would you test a premium fuel only car with regular fuel, ever, since both the cert fuel and real-world required fuel are high-octane?

UCS also commented more specifically on the impact of the adjustment from Tier 2 to Tier 3 fuel related to the knock threshold for advanced engines, noting that manufacturers consider different approaches to different fuels, and not all of those approaches necessitate reductions in efficiency, as the agencies' assumption suggests. UCS stated that charge cooling can reduce knock in direct injection engines, resulting in an "effective octane" difference of a six point increase for E10, thus potentially compensating for the difference in octane between Tier 2 (E0 93 AKI) and Tier 3 (E10 87 AKI) fuels. UCS argued that excluding this consideration led the agencies to restrict advanced engines like HCR2 and reduce the effectiveness of turbocharged engines with CEGR. UCS suggested that there would be a reduction in the costs between the baseline and proposed standards if the analysis allowed the application of HCR2 engines and corrected the effectiveness of turbocharged CEGR engines.

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[662] Ford Motors, Attachment, Docket No. EPA-HQ-OAR-2018-0283-5691, at p. 7. [double check the docket]
[663] International Council on Clean Transportation, Attachment 3, Docket No. NHTSA-2018-0067-11741, at 1-82; Union of Concerned Scientists, Technical Appendix, Docket No. NHTSA-2018-0067-12039, at p. 15.

Both ICCT and UCS also stated that the adjustment ignored a 2018 EPA study showing that, while fuel consumption increases with the switch from Tier 2 to Tier 3 test fuel, emissions are reduced, meaning that the agencies' adjustment is wrong "for some technologies because [CO_2]-per-mile emissions can be lower with the switch to higher octane ethanol blends." UCS also stated that the adjustment factor applied is wrong for two reasons, first because converting solely with energy density would assume a 3.7 percent increase in fuel consumption compared to the observed 2.7 percent increase, and second because the adjustment goes in the wrong direction when applied to CO_2 emissions, which show a reduction of 1.4 percent on the test cycle. UCS stated that the Autonomie model accordingly overstates CO_2 emissions on Tier 3 fuel by 4.2 percent. UCS argued that the adjustment to account for Tier 3 test fuel therefore double counts any penalty in fuel economy and ignores CO_2 tailpipe reductions, which would result in an improvement on the test cycle. Because the CAFE test procedure already has an adjustment in place to correct for fuel properties relative to 1975 test fuel, but carbon-related exhaust emissions do not, UCS stated that the fuel adjustment could lead to drastically conservative fuel economy and CO_2 curves.

ICCT stated that the agencies could fix this issue by relying on EPA's engine maps, where EPA had accounted for cost and effectiveness of technology used to protect operation on regular octane fuel by increasing costs and reducing effectiveness.

Some of these comments can be addressed with a simple clarification: the NPRM contained text that was inconsistent regarding how the analysis accounted for the engine maps (which were based on Tier 3). The separate model documentation correctly described that, for the NPRM analysis, the agencies developed fuel maps for Tier 3 fuel and did not adjust the final Autonomie outputs.[664] The NPRM text, however, incorrectly stated that "(a)n adjustment factor was applied to the Autonomie simulation results to adjust them to reflect Tier 2 certification fuel. ANL adjusted the vehicle fuel economy results to present certification fuel by using the ratio of the lower heating values to the rest and certification fuels." In fact, no adjustments were made to the NPRM Autonomie simulation outputs, as the modeled engine maps were appropriately modeled using Tier 3 fuel.

As discussed in detail in Section [Fuel Octane], engine specifications used to create the engine maps for the NPRM and the final rule were developed using Tier 3 fuel to assure the engines were capable of operating on real world regular octane (87 pump octane = (R+M/2)), similar to what manufacturers have told us they must do to ensure engines have acceptable noise, vibration, harshness, drivability and performance levels, and are durable and will not fail prematurely when operated on regular octane fuel. For example, if the agencies developed engine maps based on Tier 2 fuel alone, those engine maps would reflect higher compression ratios and greater levels of spark advance than could be implemented by manufacturers because they would lead to engine durability and noise, vibration, harshness, and drivability issues when operated using the regular octane fuels that the majority of vehicles consume. Manufacturers have told the agencies that, even for vehicles designed to operate on high octane fuel, the engines and controls must be designed to be capable of operating on every fuel that is available in the

Commented [A229]: REVISE: The example is confusing. Exactly what engines are being referred to where the compression ratio is/was changed?

Also, more particularly: almost all engine change spark advance continuously, and so will behave (slightly) differently with Tier 2 and Tier 3 fuels. Requiring engines to perform adequately using real-world pump gas is desirable, but that does not mean the same map should be used for simulating cert testing with Tier 2 fuel. – In other words, this response conflates real-world performance with certification requirements.

[664] [cite Autonomie model documentation that states no adjustment for Tier 3 fuel].

U.S. to avoid these issues.[665] Therefore, developing engine maps based on Tier 2 fuel alone would overstate the BSFC improvements that could be achieved in the real world.

Based on these comments and considerations, the agencies determined the engine maps developed for the NPRM appropriately account for fuel octane, and provide ~~the best available~~an appropriate estimate of BSFC that can be achieve in the real world. The agencies believe ICCT's and other commenters' assertions that the engine maps should reflect Tier 2 fuel and not be updated for Tier 3 fuel would ignore these important considerations, and would provide engine maps that could not be achieved by engines in the real world. ~~The agencies determined that engine maps developed for the Draft TAR and EPA Proposed Determination that were based on Tier 2 fuel should not be used for the NPRM and final rule analyses for these technical reasons.~~

EPA is addressing the impact of Tier 3 fuel on fuel economy and CO_2 emissions compliance test results as part of a separate rulemaking which may establish an adjustment to account for the impacts of the change in test fuel. Those impacts are beyond the scope of this rulemaking. The analysis for the SAFE Vehicles rulemaking uses fuel economy and CO_2 emissions of the vehicles in the MY 2017 analysis fleet as the reference for absolute fuel economy and CO_2 emissions. Because MY 2017 compliance values are based on Tier 2 fuel, and standards are based on the use of Tier 2 fuel, there is no need to make any adjustments for the differences in energy content and carbon content of Tier 2 and Tier 3 fuel. Again, those differences are being addressed by EPA in a separate rulemaking.

The agencies considered ICCT's statement that manufacturers that label vehicles as "premium fuel required" are required to show no emissions changes over all test cycles when using regular octane fuel, and therefore reducing effectiveness for fuel differences as the agencies did with the IAV engine maps is unrealistic and inappropriate. The agencies believe this logic is inverted, and those conclusions are technically incorrect. ~~The existence of an EPA compliance regulation does not impact the laws of nature, which govern issues associated with the impact of fuel octane on the ability to improve engine BSFC and on engine durability, noise, vibration, harshness, and drivability.~~ It is widely recognized and accepted that higher octane fuels allow engines, should the manufacturer choose to calibrate the engine to do so, to be designed with higher compression ratios, faster combustion rates, and more optimal spark advance, which improve BSFC. Section [fuel octane] discusses comments advocating for increasing the minimum fuel octane specification to enable these improvements. The engine maps developed by IAV and used for the Draft TAR and NPRM were consistent with these trends and showed that BSFC is better with Tier 2 (higher octane) fuel than Tier 3 (lower octane) fuel. ICCT did not provide any data supporting the concept that there is no shift in BSFC, fuel economy, or CO_2 emissions when engines are optimized with different octane fuels, or between Tier 2 and Tier 3 fuel. It is appropriate to note that the EPA regulation does provide a tolerance which in practice allows a small level of shift in emissions.[666]

Commented [A230]: DELETE: This does not accurately characterize EPA's view, which is that engine maps should account for BOTH Tier 2 fuel (for certification), and Tier 3 fuel (for real world calibration, fuel use and emissions)

Commented [A231]: REVISE: See above comment – this is supposed to be manufacturers that do NOT label vehicles as "premium fuel required," right?

Commented [A232]: DELETE: This is a bit unprofessional in tone, as well as missing the point. Higher octane fuels allow lower fuel consumption if the manufacturer chooses to calibrate the engine to do so. It does not require lower fuel consumption. Invoking the "laws of nature" is far overstating the case, and not responsive to the comment.

[665] [Citation for this]
[666] [EPA reg citation]

Regarding comments that certain combinations of technologies can enable BSFC improvements while controlling spark knock, the agencies in fact considered a very broad array of engine technology combinations for the analysis, including several added technologies as discussed further below. The agencies believe the rigorous methodology used to develop the engine maps resulted in engine maps representing the maximum improvement in BSFC for each engine configuration, while also addressing real world constraints. Engine maps for the new technologies were presented in PRIA Chapter 6.3.2.2.16.4. The PRIA also discussed that IAV maps were developed considering a very comprehensive list of combustion operating parameters as part of the IAV GT-Power engine modeling. IAV's GT-Power engine modeling included sub-models to account for heat release through a predictive combustion model, knock characteristic through a kinetic fit knock model, physics-based heat flow model physics based friction model, and IAV's proprietary Optimization Tool Box.[667] These independent models were run concurrently to make sure engine design requirements were met for each engine configuration that was modeled.

A simple example of how this process works can be discussed in few steps. First, IAV defined the characteristics of Eng01 (a base VVT engine) and then optimized for all the combustion parameters while minimizing fuel consumption and maintaining performance. The result of this was a fuel map as a function of BMEP and engine RPM. Next, IAV took the same Eng01 and adopted characteristics of SGDI technology to the base engine. This new Eng18 (VVT and SGDI) was then optimized for all the combustion parameters while minimizing fuel consumption and maintaining performance. The result was an engine fuel map as a function of BMEP and engine speed for Eng18 with SGDI technology. The engine map is directly comparable to the engine map for Eng01 and the difference in those engine maps specifically identifies the effectiveness impact of VVT and SGDI technologies alone. This process was repeated for all of the IAV engine maps that used the base VVT (Eng01) as the baseline engine. This methodology ensured the engine maps represent the maximum improvement in BSFC for each engine configuration, while considering real world design constraints.

Finally, in response to the agencies' request for comment on whether to include the additional engine maps presented in the NPRM as potential technological pathways to fuel economy improvement in the model, several commenters stated that the agencies should include those engine maps, in addition to other emerging engine technologies.

After considering these comments, the agencies added several engine technologies and technology combinations for the final rule analysis. These included a basic high compression ratio Atkinson mode engine (HCR0), a variable compression ratio engine (VCR), a variable turbo geometry engine (VTG), and a variable turbo geometry with electric assist engine (VTGe). The agencies also added advanced cylinder deactivation technology (TURBOAD) to Eng12 (TURBOD) in the Autonomie modeling for the final rule analysis. Like with ADEAC, the agencies did not have IAV engine maps for TURBOAD, so the agencies took the effectiveness

[667] IAV's Optimization Tool Box is a module of IAV Engine. IAV Engine, as the basic platform for designing engine mechanics, provides a large number of tools that have proven their worth across the globe in several decades of automotive development work at IAV. The modules help designers, computation engineers and simulation specialists in designing mechanical engine components—for example, in laying out valvetrains and timing gears as well as crankshafts.

values as predicted by full vehicle simulations of a TURBOD and added 1.5% or 3% respectively for I-4 engines and V-6 or V-8 engines, as explained in more detail further below. The agencies also included more iterations of existing technologies, like diesel engines with cylinder deactivation, diesel engines paired with manual transmissions, and diesel engines paired with 12-volt start stop technology, in addition to more combinations of hybrid technologies that are discussed further in [Section Electrification], below.

The following sections list and describe the comprehensive set of engine technologies and combinations of engine technologies that have been included in the analysis. The agencies also discuss the additional engine technologies added for the final rule, and reasons for excluding a small number of technologies proffered by commenters. The agencies believe the wide array of engine technologies included in the final rule analysis and the methodology used to develop the engine maps to measure the effectiveness of those technologies reasonably represents the scope of technologies that should be considered during the rulemaking timeframe.

c) Engine Modeling in the CAFE Model

(1) Basic Engines

The NPRM described that there are a number of engine technologies that manufacturers can use to improve fuel economy and CO_2 emissions. Some engine technologies can be incorporated into existing engines with minor or moderate changes to the engines, but many engine technologies require an entirely new engine architecture. The terms "basic engine technologies" and "advanced engine technologies" are used only to define how the CAFE model applies a specific engine technology and handles incremental costs and effectiveness improvements. "Basic engine technologies" refer to technologies that, in many cases, can be adapted to an existing engine with minor or moderate changes to the engine, compared to "advanced engine technologies" that generally require significant changes or an entirely new engine architecture.

In the CAFE model, basic engine technologies may be applied in combination with other basic engine technologies; advanced engine technologies (defined by an engine map) stand alone as an exclusive engine technology. The words "basic" and "advanced" are not meant to confer any information about the level of sophistication of the technology. Also, many advanced engine technology definitions include some basic engine technologies, but these basic technologies are already accounted for in the costs and effectiveness values of the advance engine. The "basic engine technologies" need not be (and are not) applied in addition to the "advanced engine technologies" in the CAFE model.

(a) DOHC

In the NPRM analysis, the agencies characterized dual overhead cam (DOHC) engine technology as "basic." DOHC engine configurations have two camshafts per cylinder head, one operating the intake valves and one operating the exhaust valves. Four basic engine technologies—Variable Valve Timing (VVT), Variable Valve Lift (VVL), Stoichiometric Gasoline Direction Injection (SGDI), and basic Cylinder Deactivation (DEAC)—were

considered for DOHC engines. Implementing these technologies involves changes to the cylinder head of the engine, but the engine block, crankshaft, pistons, and connecting rods require few, if any, changes.

Variable Valve Timing (VVT) is a family of valve-train designs that dynamically adjusts the timing of the intake valves, exhaust valves, or both, in relation to piston position. VVT can reduce pumping losses, provide increased engine torque and horsepower over a broad engine operating range, and allow unique operating modes, such as Atkinson cycle operation, to further enhance efficiency. VVT is nearly universally used in the MY 2017 fleet.[668] In the NPRM analysis, the VVT technology modeled by IAV was based on dual (independent) cam phasing. This was a more advanced VVT technology that allowed controlling of valve overlap, which can be used to control internal EGR to minimize fuel consumption at low engine loads.[669] VVT enables control of many aspects of air flow, exhaust scavenging, and combustion relative to fixed valve timing engines. Engine parameters such as volumetric efficiency, effective compression ratio, and internal exhaust gas recirculation (iEGR) can all be enabled and accurately controlled by a VVT system.

Variable Valve Lift (VVL) dynamically adjusts the distance a valve travels from the valve seat optimizing airflow over a broad range of engine operating conditions. The technology can increase effectiveness by reducing pumping losses and may improve efficiency by affecting in-cylinder charge (fuel and air mixture), motion, and combustion. VVL is less common in the 2017 fleet than VVT. Some manufacturers have implemented a limited, discrete approach to VVL where just two valve lift profiles are available versus a full-range, continuously variable implementation.

Stoichiometric Gasoline Direct Injection (SGDI) sprays fuel at high pressure directly into the combustion chamber, which provides cooling of the in-cylinder charge via in-cylinder fuel vaporization to improve spark knock tolerance and enable an increase in compression ratio and/or more optimal spark timing for improved efficiency. SGDI appears in about half of basic engines produced in MY 2017, and the technology is used in many advanced engines as well.[670]

Basic cylinder deactivation (DEAC) disables intake and exhaust valves and turns off fuel injection for the deactivated cylinders during light-load operation. The engine runs temporarily as though it were a smaller engine, which reduces pumping losses and improves efficiency. In the MY 2017 fleet, manufacturers used DEAC on V6, V8, V10, and V12 engines on OHV, SOHC, and DOHC engine configurations. With some engine configurations in some operating conditions, DEAC creates noise-vibration-and-harshness (NVH) challenges. NVH challenges are significant for V6 and I4 DEAC configurations, and limit the operating range where DEAC can operate. For I4 engine configurations with smaller displacements, there are fewer operating

[668] 98.1% of MY2017 vehicles are equipped with VVT. EPA Report. *The 2018 EPA Automotive Trends Report*. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100W5C2.PDF?Dockey=P100W5C2.PDF at Table 4.1 Production Share by Engine technology.
[669] 2015 NAS at p. 32.
[670] 49.7% of MY2017 vehicles are equipped with SGDI. EPA Report. The 2018 EPA Automotive Trends Report. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100W5C2.PDF?Dockey=P100W5C2.PDF at Table 4.1 Production Share by Engine technology.

conditions where engine load is low enough to use DEAC, which limits effectiveness. No manufacturers produced I4 DEAC engines in MY 2017. Typically, the smaller the engine displacement, the less opportunity DEAC provides to improve fuel consumption.

The agencies provided engine fuel maps for each of the eight DOHC engines (Eng01, Eng02, Eng03, Eng04, Eng18, Eng19, Eng20, and Eng21) used for the NPRM analysis. Each of these engines incrementally added technology to Eng01, a basic VVT engine, while holding all other factors constant like ambient temperature, ambient pressure, and fuel type. The agencies sought comment on the engine maps.

For the NPRM analysis, the agencies estimated the effectiveness of DEAC using full vehicle modeling and simulation. In the NPRM PRIA 6.2.1.2, we discussed how Autonomie uses a specific control logic for cylinder deactivation for naturally aspirated engines that takes into consideration for noise, vibration, and harshness.[671] For the final rule analysis, the agencies took steps to use full vehicle modeling and simulation to apply DEAC to both naturally aspirated and turbocharged engines. The same control logic was applied to the turbocharged engine cylinder deactivation (TURBOD) for the final rule analysis.

The agencies used the same assumptions for ADEAC in the final rule analysis. In the NPRM we stated engine maps were not available at the time of the analysis, and said that ADEAC was estimated to improve a basic engine with VVL, VVT, SGDO, and DEC by three percent (for 4 cylinder engines) and six percent (for engines with more than 4 cylinders).[672] The new technology combination for turbocharged advanced cylinder deactivation (TURBOAD) uses a similar approach for determining effectiveness. The agencies have applied a one-and-a-half percent effectiveness improvement estimate for 4-cylinder or smaller engines and a three percent effectiveness estimate for 6-cylinder or larger engines relative to TURBOD.

For the final rule analysis the basic engine path for DOHCs are shown in Figure VI-8 and the high-level engine specifications are shown in Table VI-22. The baseline basic DOHC engine, Eng01, was the starting point and other engine technologies were incrementally adopted to determine effectiveness. Adoption of DEAC technology for turbocharged engines will be discussed in Turbocharged Engines section [x]. Similarly, Advanced DEAC technology will be discussed in [Section X].

[671] NHTSA-2018-0067-1972. "Preliminary Regulatory Impact Analysis (PRIA) The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021-2026 Passenger Cars and Light Trucks," at p. 191.
[672] 83 FR 430039 (Aug. 24, 2018).

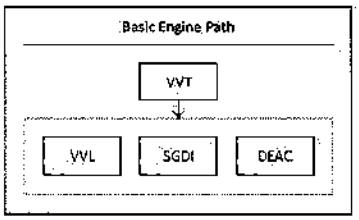


Figure VI-8 - Basic Engine Technologies for DOHC Engines for the Final Rule Analysis

Table VI-22 - Specifications for DOHC Basic Engine Technologies Modeled by Autonomie for the Final Rule Analysis

Engines	Technologies	Notes	Engine Reference Peak Power (kW)
Eng01	DOHC VVT	Parent NA engine, Gasoline, 2.0L, 4 cyl, NA, PFI, DOHC, dual cam VVT, CR10.2	108
Eng02	DOHC VVT+VVL	VVL added to Eng01	108
Eng03	DOHC VVT+VVL+SGDI	SGDI added to Eng02, CR11	113
Eng04	DOHC VVT+VVL+SGDI+DEAC	Cylinder deactivation added to Eng03	113
Eng18	DOHC VVT + SGDI	Gasoline, 2.0L, 4 cyl, NA, SGDI, DOHC, dual cam VVT	113
Eng19	DOHC VVT + DEAC	Cylinder deactivation added to Eng01	113
Eng20	DOHC VVT + VVL + DEAC	Cylinder deactivation added to Eng02	113
Eng21	DOHC VVT + SGDI + DEAC	Cylinder deactivation added to Eng18	113

(b) SOHC

Similar to DOHC engines, SOHC engines were characterized as "Basic" Engine technologies in the NPRM analysis. They are characterized by having a single camshaft in the cylinder head operating both the intake and exhaust valves. Four basic engine technologies, Variable Valve Timing (VVT), Variable Valve Lift (VVL), Stoichiometric Gasoline Direction Injection (SGDI), and basic Cylinder Deactivation (DEAC) were considered for SOHC engines. Implementing these technologies involves changes to the cylinder head of the engine, but the engine block, crankshaft, pistons, and connecting rods require few, if any, changes.

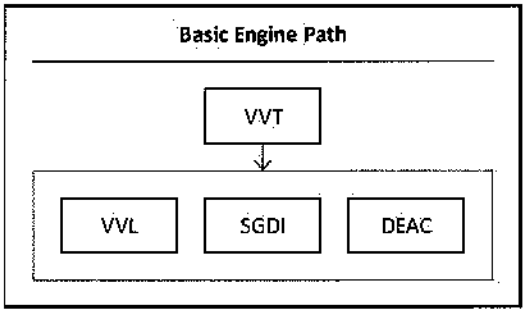
The agencies provided engine fuel maps for each of these types of SOHC engines and requested comments. Engine maps 5b, 6a, 7a, and 8a were modeled SOHC engines. The SOHC engine models used engine 5a which was based on Eng01 as a reference by removing one

camshaft. Eng5a was included for the Draft TAR, but not included for the NPRM analysis due to high BSFC from higher friction that was inherited from the DOHC engine design. A level 0.1 bar of friction reduction over the entire operating range for engine maps 5b, 6a, 7a, and 8a was applied to represent improvements over existing engine designs. The addition of friction reduction to these engines was a result of consideration of deliberative interagency comments received during the Draft TAR review process noting higher fuel consumption on the baseline SOHC engine 5a relative to other modern SOHC engines.[673]

Meszler on behalf of NRDC commented that "[a]lthough variable valve timing (VVT) technology is identified as an available refresh technology, the NPRM CAFE model (unlike the version used for the 2016 TAR analysis) actually assumes that all baseline vehicles include VVT technology. As a result, the approximately 9 percent of model year 2016 sales that do not actually include VVT are not credited with any efficiency benefit for adoption of the technology…."[674]

We agree with this comment, and for the final rule analysis the agencies updated the CAFE model to add a non-VVT level engine in the 2017 analysis fleet and to allow those vehicles to adopt VVT technologies at a refresh or redesign. However, the agencies did not have engine maps for the non-VVT engines, so we applied an effectiveness to the VVT engine maps to represent the effectiveness for non-VVT engines. The agencies used the effectiveness of a similar configuration technology package of another engine to represent non-VVT engines. Non-VVT may be combined with any combination of VVL with SGDI and DEAC. We believe that the estimated effectiveness used for VVT engines was appropriate because the effectiveness offset is in line with 2015 NAS estimates for VVT engines with respect to VVL engines.[675]

For the final rule making analysis the basic engine paths for SOHC engines are shown in Figure VI-9 and the specifications are shown on Table VI-23. Note, that Eng5a is only a reference used to build the rest of the SOHC engines.



[673] [Text Forthcoming].
[674] Meszler, at p. 32.
[675] 2015 NAS Table 2.7 and Table 2.8 at p. 32-33.

Figure VI-9 - Basic Engine Technologies for SOHC Engines for Final Rule Analysis

Table VI-23 - Specifications for SOHC Basic Engine Technologies Modeled by Autonomie for the Final Rule Analysis

Engines	Technologies	Notes	Engine Reference Peak Power (kW)
Eng5a	SOHC VVT+PFI	Eng01 converted to SOHC (gasoline, 2.0L, 4cyl, NA, PFI, single cam VVT)	Reference only
Eng5b	SOHC VVT (level 1 Red. Friction)	Eng5a with valvetrain friction reduction (small friction reduction)	109
Eng6a	SOHC VVT+VVL (level 1 Red. Friction)	Eng02 with valvetrain friction reduction (small friction reduction)	109
Eng7a	SOHC VVT+VVL+SGDI (level 1 Red. Friction)	Eng03 with valvetrain friction reduction (small friction reduction), addition of VVL and SGDI	114
Eng8a	SOHC VVT+VVL+SGDI+DEAC (level 1 Red. Friction)	Eng04 with valvetrain friction reduction (small friction reduction), addition of DEAC	114

(2) Turbocharged Downsized Engines

Engine maps 12, 13, and 14 modeled turbocharged downsized engines. Turbocharged downsized engines are characterized by technology that can create greater-than-atmospheric pressure in the engine intake manifold when higher output is needed. The raised pressure results in an increased volume of airflow into the cylinder supporting combustion, increasing the specific power of the engine. An increased specific power means the engine can generate more power per unit of volume; which allows engine volume to be reduced while maintaining performance, thereby increasing fuel efficiency. IAV Eng12 was the base engine for all simulated turbocharged engines and was validated using engine dynamometer test data.

One notable change that the agencies made for the NPRM analysis based on stakeholder comments to the Draft TAR was to update the turbo family engine maps to assume operation on regular octane fuel (Tier 3, or 87 AKI), instead of premium fuel (Tier 2, or 93 AKI), to assure the maps accounted for real world constraints that impact durability and drivability, and noise, vibration, and barshness. Using regular octane fuel is consistent with the fuel octane that manufacturers specify be used in the majority of vehicles (manufacturers generally only specify premium fuel is required for higher performance models, although that is not always the case), and enables the modeling to account for important design and calibration issues associated with regular octane fuel. The agencies noted in the NPRM that using the updated engine maps addresses over-estimation of potential fuel economy improvements and ensures that the analysis reflects real-world constraints faced by manufacturers to assure engine durability and acceptable drivability. Importantly, assuming no change in fuel octane required to operate a vehicle ensures that the agencies are modeling technology pathways that can improve fuel economy while maintaining vehicle performance, capability, and other attributes.

Compared with the NHTSA analysis in the Draft TAR, the turbocharged and downsized engine maps adjust the fuel use at high torque and low speed operation and at high speed operation to account for knock limitations necessary when using regular octane fuel. The knock model used to develop the turbocharged engines was trained on production and development engines tested at IAV to quantify the effects of different octane fuels.[676] Below the knock threshold, there is no change to the fuel consumption maps. The agencies noted that with the fuel octane change, there are generally two major effects in the regions where the engine is knock-limited: first, spark timing is retarded causing a reduction in combustion efficiency and hence an increase in BSFC, and second, an increase in combustion temperature requires fuel enrichment for the component protection resulting in increased BSFC.[677, 678]

Commented [A233]: **REVISE:** Pointing out that this is inconsistent with statements above that operation at high speeds and loads is not relevant to the two-cycle simulation.

The agencies also noted that for Eng14, the turbocharged downsized engine with cooled exhaust gas recirculation (cEGR), cEGR was added at the higher speeds where further reduction in combustion temperature was required. The higher specific heat capacity of cEGR reduced the need for fuel enrichment by lowering combustion temperatures and limiting the amount of spark retardation necessary to manage spark knock. With increasing load, cEGR is also used to lower combustion temperatures to reduce NOx emissions. The agencies explained that because IAV's models are not trained for emissions, cEGR was only considered for areas that are knock-limited and/or to reduce combustion temperatures. Because cEGR has the impact of slowing down burn rates, the amount of cEGR that could be utilized was balanced to maintain efficient combustion. Combustion stability was also evaluated to assure cEGR rates did not cause excessive cycle-to-cycle combustion variations which adversely impact drivability.[679]

Some commenters criticized these downsized turbocharged IAV maps, referencing draft deliberative EPA comments ~~from some EPA staff~~ that was docketed pursuant to [CAA section x], which stated that the assumptions for Eng12's fuel octane, heating value, and carbon content were not representative of certification fuel and did not appear to be consistently used for the various engine maps, concluding that the resultant engine maps were not representative of CO_2 performance of turbocharged engines over the certification cycle. ICCT stated it appeared these concerns had not been addressed for the NPRM, and that "this problem essentially affect[ed] all engines on the turbocharged engine pathway."[680]

Commented [A234]: **REVISE:** Why is it necessary to say so?

The agencies disagree with ICCT's comments relating both to whether fuel specifications were used consistently and whether the fuel specifications for fuel octane, heating value and carbon content were representative of the same fuel. First, the EPA deliberative comments were resolved in the deliberative process through the clarification that a single fuel specification was

[676] Knock models are based on Gamma Technology's kinetic fit model per the technical paper titled, "A combustion model for IC engine combustion simulations with multi-component fuels," by YoungChul Ra, Rolf D. Reitz – Engine Research Center, University of Wisconsin-Madison.
[677] Fuel enrichment is extra fuel is injected in port or directly into the cylinder to suppress thermal shocks like uncontrolled detonation (also known as knock).
[678] Singh, E. and Dibble, R., "Effectiveness of Fuel Enrichment on Knock Suppression in a Gasoline Spark-Ignited Engine," SAE Technical Paper 2018-01-1665, 2018, https://doi.org/10.4271/2018-01-1665.
[679] Heywood, B. J, Internal Combustion Engine Fundamentals, at pp. 413-37, McGraw-Hill (1988).
[680] International Council on Clean Transportation, Attachment 3, Docket No. NHTSA-2018-0067-11741, at I-46.

used to develop all of the engines and engine maps. Therefore, the engine maps are internally consistent. The fuel specification was presented in the NPRM section [2D.1] and PRIA Chapter 6.3.2.2.17. Second, we considered future fuel and emissions standards by using regular octane fuel for this analysis. The assumptions for the fuel used in this analysis align with the EPA's Tier 3 standards that went into effect January 1, 2017.[681] For the reasons discussed further above, the agencies believe it is important to use Tier 3 fuel for engine maps used for rulemaking analysis.

Roush claimed that the turbocharged engine maps used in the analysis were responsible for an overly-conservative estimate of underlying combustion engine efficiencies, arguing that many production engines available today use the same technology packages identified in the PRIA but with significantly higher efficiencies.[682] Roush noted that the base turbocharged engine map used in the PRIA, Eng12, is assumed to have variable valve lift (VVL), but with a turbocharged engine the benefit of VVL over dual variable valve timing (VVT) is limited.[683] Roush argued that almost all vehicle manufacturers use lower-cost dual VVT systems in their turbocharged engines, and that the agencies' base turbocharged engine assumption is unrealistic with a correspondingly high cost.[684]

Roush contrasted its critique of Eng12 with an EPA ALPHA run of a 2016 Honda Civic 1.5L turbocharged engine (L15B7) with continuously variable intake and exhaust camshaft phasing (CVVT), which is less expensive than the CVVL, arguing that it showed greater efficiency over more of the engine map at a lower cost than Eng12. Roush further argued that since the L15B7 engine is the first generation of the new Honda turbocharged engine, "even further fuel consumption improvement is highly likely in the period through MY2025."[685]

As the agencies explained further above, from a technical perspective there is no reason why the 2016 Honda Civic 1.5 L Turbo should have an engine map that is the same as Eng12, Eng13, or Eng14. The turbocharged engine technologies represented by Eng12, Eng13 and Eng14 are not representative of any specific engine from any one manufacturer. Honda's 1.5L turbocharged engine incorporates a unique combination of technologies including electric wastegate, sodium-filled exhaust valves, light weight internal components, friction reduction technologies, 2-stage oil pump, low viscosity oil (0W-20), and a unique exhaust system.[686]

While there are an enormous number of different technology combinations that manufacturers could apply on their engines, the agencies' analysis must select a reasonable number of configurations—in fact, the agencies analyze more than [XX] technological/vehicular

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[681] [*Final Rule for Control of Air Pollution from Motor Vehicles: Tier 3 Motor Vehicle Emission and Fuel Standards*. https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-motor-vehicles-tier-3. Last accessed September 26, 2019.]

[682] Roush Industries on behalf of California Air Resources Board, Rogers_Final_Final_NPRM_10.26.2018, Docket No. NHTSA-2018-0067-11984, at [x].

[683] Roush Industries on behalf of California Air Resources Board, Rogers_Final_Final_NPRM_10.26.2018, Docket No. NHTSA-2018-0067-11984, at [x].

[684] Roush Industries on behalf of California Air Resources Board, Rogers_Final_Final_NPRM_10.26.2018, Docket No. NHTSA-2018-0067-11984, at [x].

[685] [citation]

[686] [citation]

combinations for this rulemaking. See Section [Performance Neutrality] and Section [Tech Effectiveness and Modeling] for more details. For turbocharged engines, the agencies selected eight combinations that we believe represent a wide range of technologies, combinations of technologies, and effectiveness improvements for the rulemaking analysis, as listed in Table [FRM engine list]. Three of the combinations were added based on commenter's recommendations. While it is possible to identify other combinations, such as the unique technologies Honda chose for its 1.5L Turbo engine, agencies do not believe it would be appropriate to select all of the technologies on one specific manufacturer's engine for the rulemaking analysis. Doing so would, appropriately, raise questions about the availability of proprietary designs and controls to other manufacturers, among other considerations.

The agencies also believe that the engine maps for Eng12, Eng13 and Eng14 show reasonable differences in BSFC maps that characterize the impact of each of these technology combinations, and differences relative to naturally aspirated engines. As discussed further above, incremental differences in BSFC are used for the rulemaking analysis. Roush's comments center on the comparison of absolute effectiveness values for a specific production vehicle, and do not address incremental effectiveness among a range of technologies, nor the appropriate baseline reference for the Honda 1.5L Turbo for technology content and for effectiveness. The ALPHA simulation for the 2016 Honda Civic 1.5L turbocharged engine provides absolute test data and has no baseline for assessing incremental effectiveness. Because there is no baseline, there is no basis for identifying which specific technologies have changed, nor any basis for determining the incremental effectiveness of each individual technology.

Regarding Roush's comment that that further fuel consumption improvement for the Honda L15B7 is highly likely in the period through MY 2025, Roush provided no information or data on what specific technologies would further improve the fuel consumption of that engine. With no defined new technology to consider, there is no basis for estimating the costs, nor for estimating the effectiveness of Roush's assertion. Without further information, the agencies can only point to the additional engine technologies considered for this final rule, discussed further below.

ICCT also stated that IAV's handling of Cooled EGR ("cEGR") in the engine maps is inappropriate, as IAV analyzed cEGR as a knock-abatement technology instead of a fuel efficiency technology. ICCT stated that this is reason that the NPRM analysis shows no benefit to cEGR, and if the agencies had used EPA's properly modeled cEGR effectiveness based on validated data, the effectiveness of cEGR would have been more realistic.

Similarly, Roush commented that cEGR application in the modeled turbocharged engines is excluded in engine operating modes that highly influence vehicle fuel economy. Roush contrasted Eng13, a turbocharged engine with VVT, direct injection, and cEGR, with the Mazda 2.5L SkyActiv Turbo engine available in the 2016 Mazda CX-9, which also employs cEGR.

The agencies believe Eng14 was created and modeled using a sound technical methodology, using constraints that the industry uses to ensure the engines would meet durability and customer acceptability criteria. Engines with VVT control intake and exhaust valve timing to recycle burned exhaust gas into the combustion chamber. The recycling of exhaust gases

using VVT is commonly called internal EGR. Cooled EGR (cEGR) is a *second* method for diluting the incoming air, which takes exhaust gases, passes them through a cooler to reduce their temperature, and then mixes them with incoming air in the intake manifold. Diluting the incoming air with inert exhaust gas reduces pumping losses, thereby improving BSFC. The dilution also reduces combustion rates, temperatures, and pressures, which mitigates spark knock and reduces the need for fuel enrichment at higher loads to control exhaust temperature for component durability (typically, exhaust valves and exhaust manifold). Not only does this exhaust gas displace some incoming air, but it also heats the incoming air and lowers its density. Both interactions lower the volumetric efficiency of the engine.[687] Cooled EGR is a more effective way of reducing combustion temperature in higher load and higher speed engines like turbocharged engines.

Commented [A235]: REVISE: This is confusing to and seems to be non-responsive to the comment. Roush is commenting that cEGR is used by the turbo Mazda engine to improve BSFC, and this tech was not properly incorporated into the IAV engine maps. The response seems to simply state that cEGR does not, in fact, improve BSFC in turbos, with no evidence to support that.

As mentioned above, IAV developed engine specifications, including the rate of internal EGR and cEGR, using criteria used by industry to ensure the engines would meet durability and customer acceptability criteria. In addition to reducing pumping losses, EGR slows the combustion rate and causes combustion to be less consistent cycle-to-cycle as the concentration increases. Industry and researchers use a measurement known as Coefficient of Variation of Indicated Mean Effective Pressure (COV of IMEP) to evaluate combustion stability. Industry commonly recognizes values greater than 3.0 percent as unacceptable because above those levels, the combustion instability creates a noticeable and objectionable drivability problem for vehicle occupants, referred to as "surge." Surge is perceived as the vehicle accelerating and decelerating erratically, instead of running smoothly. IAV set EGR rates at each of the engine operating conditions at the highest level that did not exceed 3.0 percent COV of IMEP. Therefore, the IAV engine maps *did* maximize efficiency within real-world constraints, similar to how manufacturers develop their engines. At the lower speed and load conditions of the 2-cycle tests, the COV of IMEP threshold was reached using internal EGR alone, so additional cEGR was not applied. At higher load conditions, such as the US06 cycle, cEGR was applied. The ICCT assertion that the engine maps were only developed considering knock-abatement is inaccurate. In the PRIA Chapter 6.3.2.2.11, the agencies discussed the application of internal EGR in combination with cEGR for Eng14. VVT technology, with which Eng14 is equipped, maximizes EGR usage first in areas where the engine primarily operates, such as low load and low speed area like city cycle and highway cycle tests used in CAFE compliance testing. Cooled EGR is applied at higher speed and higher load conditions, such as the US06 test cycle.

~~Using EPA's modeled cEGR would have resulted in infeasible engine maps because they were developed assuming the exclusive use of high octane Tier 2 fuel, and using a COV of IMEP threshold of 5 percent, which is beyond the level that is deemed acceptable to consumers in the real world.[688] The use of these criteria results in engine maps with BSFC levels that cannot be achieved by manufacturers that must ensure their engines are durable and are acceptable to~~

Commented [A236]: DELETE: This characterization of EPA's engine maps is incorrect, and in any case is not necessary for the support of the technical analysis used in this FRM.

[687] Volumetric efficiency (VE) in internal combustion engine engineering is defined as the ratio of the mass density of the air-fuel mixture drawn into the cylinder at atmospheric pressure (during the intake stroke) to the mass density of the same volume of air in the intake manifold. Ideally, you want this to be high as possible to maximize thermal efficiency during the power stroke (combustion phase).

~~[688] [EPA Proposed Determination TSD at p. 2-295 Footnote [[[[]]]]~~

~~customers with fuels that are used and available. The reference engine for EPA's cEGR concept was 2010 Ricardo prototype V6 engine that used 98 RON fuel (93 AKI or premium fuel) to determine effectiveness.[688] The problems associated with using high octane Tier 2 to develop engine maps are discussed in detail in Section [fuel octane]. The issues associated with excessive cEGR rates and COV of IMEP, are discussed immediately above. In addition, the cEGR engine maps that EPA used were never evaluated with regular octane Tier 3 fuel to assess the further degradation BSFC and in COV of IMEP that would occur where spark advance would need to be decreased to address spark knock, as decreasing spark advance directionally makes both BSFC and COV of IMEP worse.[689] Also, because some models are still under development, ALPHA effectiveness estimates in the Draft TAR and derived for the Proposed Determination do not provide the best available basis for assessing effectiveness impacts.[690] Therefore, the assumptions used for the EPA Draft TAR and Proposed Determination engine maps overstate learable improvements and therefore do not provide meaningful comparisons to the engine maps used for the NPRM and final rule analyses.~~

Commented [A237]: CHANGE AS SHOWN: Text is not clear what point is being made, but nevertheless, not necessary to respond to comment.

Finally, Roush compared Eng13 to the 2016 Mazda SkyActiv-G 2.5L Turbo. The agencies believe these engines use technologies that are sufficiently different so as to render a comparison not useful, even for a very rough validation of Eng13. Most fundamentally, as discussed in PRIA Chapter 6.3.2.2.11 and 6.3.2.2.13, the Mazda 2.5L Turbo is a Miller cycle engine, whereas Eng13 is an Otto Cycle engine. Also, the Mazda 2.5L Turbo has cEGR, whereas Eng13 does not.[692] On a more detailed level, as described in PRIA Chapter 6.3.2.2.20.10, Eng13 has a BSFC of 238 g/kwh, whereas Roush refers to an engine having a BSFC of 250 g/kwh.[693] The agencies therefore believe comparing the 2016 Mazda SkyActiv-G 2.5L Turbo to Eng13 is not a useful or relevant comparison. In the PRIA, the agencies included an engine map for a Miller cycle engine and requested comments on whether it should be included in the final rule analysis. Based on the comments, as discussed further below, the agencies added a Miller cycle engine to the final rule analysis.

Commented [A238]: REVISE: This misses the point of the comment. Roush is comparing the best modeled engine with a current production one and asking why the modeled version doesn't include these obviously feasible technologies.

(3) Non-HEV Atkinson Mode Engines

Manufacturers use a variety of designs and technologies to obtain an engine's highest thermal efficiency while maintaining drivability and performance. While the Otto cycle has historically been used by the vast majority of gasoline based engines, one way to improve thermal efficiency is by using alternative combustion cycles. One such alternative combustion cycle that can be used in place of the Otto cycle to achieve a higher maximum thermal efficiency

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~~[688] 2016 EPA Technical Support Document at p. 2-212 in section 2.3.4.1.9 Table 2-90. EPA-420-R-16-021, September 2016. Available at https://nepis.epa.gov/Exe/ZyPDF.cgi/Index=P100QZ1.pdf~~

~~[689] 2016 EPA Technical Support Document at p. 2-212 in section 2.3.4.1.9. EPA-420-R-16-021, November 2016. Available at https://nepis.epa.gov/Exe/ZyPDF.cgi/Index=P100QZ1.pdf~~

~~[690] Advanced Light Duty Powertrain and Hybrid Analysis (ALPHA) Tool. Available at https://www.epa.gov/regulations-emissions-vehicles-and-engines/advanced-light-duty-powertrain-and-hybrid-analysis-alpha#v1.0. Version 2.2. Incomplete Models in ALPHA 2.2. TechWalk Samples Tool Tech Walk publish Escape AWD.mdrs.~~

[692] NHTSA Benchmarking, "Laboratory Testing of a 2016 Mazda CX9 2.5 I4 with a 6 Speed Transmission." DOT HS 812 519.

[693] NHTSA-2018-0067-11984 at p. 20 of 37 Figure 8.

is the Atkinson cycle. Atkinson cycle operation is achieved by modifying the Otto cycle engines' crank and valvetrain mechanics to maintain compression ratio while increasing expansion ratio.[694, 695, 696] Specifically, in Otto cycle operation, the exhaust valve is opened near the end of the power stroke, allowing exhaust gases out of the cylinder. The pressure in the cylinder is still about three to five atmospheres.[697] Currently, there are two common approaches to achieving Atkinson Cycle operation: either the exhaust valve timing or the intake valve timing are modified. In the first instance, the exhaust valve is not opened until enough expansion has occurred for the cylinder pressure to be equivalent to atmospheric pressure. The energy that typically is lost when the exhaust valve opens in Otto cycle is captured in the Atkinson cycle, leading to higher thermal efficiency. Modifying the intake valve timing, the most common way to achieve Atkinson cycle operation, involves allowing the intake valve to stay open during some portion of compression stroke. As a result, some of the fresh charge is driven back into the intake manifold by the raising piston so the cylinder is never completely filled with air, allowing optimized capture of combustion-created pressure.

While Atkinson cycle engines have higher theoretical thermal efficiency compared to Otto cycle engines, the Atkinson cycle engine delivers that higher efficiency at the cost of power density. The reduced power density is because of lower operation pressures in the cylinder than in a typical Otto cycle engine. Accordingly, Atkinson cycle engines have been ideal for hybrid vehicles because their electric motor can make up for lost power density.

As technologies have become more sophisticated, descriptions of Atkinson cycle engines and Atkinson mode engine technologies have been used interchangeably, and often incorrectly, in association with High Compression Ratio (HCR) engines by the agencies and stakeholders. Although they both achieve an overall higher thermal efficiency than Otto cycle only engines, they differ in execution depending on engine load. For the following discussion, Atkinson technologies considered in the analysis can be categorized into three groups: (1) Atkinson engines, (2) Atkinson-mode engines, and (3) Atkinson-enabled engine, which are variable valve timing engines with late intake closing that enables the Atkinson cycle mode. As discussed earlier, because power density is traded for efficiency, there is a limit to where Atkinson technology can be applied. While any vehicle could, theoretically, adopt an Atkinson-mode engine or an engine that enables operating in Atkinson cycle mode, the differeuce in vehicle application (high-performance versus standard-performance vehicles, towing requirements, trucks) leads to different effectiveness levels. The range of effectiveness appeared to create confusion between stakeholders regarding how the technology is applied to vehicles for compliance modeling and simulation.

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[694] Otto cycle is a four-stroke cycle that has four piston movements over two engine revolutions for each cycle. First stroke: intake or induction; seconds stroke: compression; third stroke: expansion or power stroke; and finally fourth stroke: exhaust.

[695] Compression ratio is the ratio of the maximum to minimum volume in the cylinder of an IC engine.

[696] Expansion ratio is the ratio of maximum to minimum volume in the cylinder of an IC engine when the valves are closed (*i.e.* the piston is traveling from top to bottom to produce work).

[697] Pulkrabek. W. W. "Engineering Fundamentals of the Internal Combustion Engine." 2nd edition. Pearson Prentice Hall, at p. 118.

Atkinson engines are engines that operate full-time in the Atkinson cycle. As mentioned above, the most common method of operation used by Atkinson engines currently is late intake closing. This approach allows backflow from the combustion chamber into the intake manifold, reducing the dynamic compression ratio, but providing a higher expansion ratio. This improves thermal efficiency but reduces power density. As a result of limited engine operation, these engines tend to have lower specific power.[698] The lower specific power tends to relegate these engines to hybrid vehicles applications, as coupling the engines to electric motors can compensate for the lower specific power. The Toyota Prius is an example of a vehicle that uses an Atkinson engine. Typically, vehicles that use an Atkinson cycle engine incorporate various fuel-efficient technologies like aerodynamic improvements, advanced continuously variable transmissions, mass reduction, and many other technologies to minimize engine load and attain high thermal efficiency.[699] The 2017 Toyota Prius achieved a peak thermal efficiency of 40%.[700]

Atkinson-mode engines are engines that use both the Otto cycle and Atkinson cycle during operation, switching between the modes of operation based on engine loads. During high loads the engine will operate in the power-dense Otto cycle mode, while at low loads the engine will operate in the higher-efficiency Atkinson cycle mode. The magnitude of efficiency improvement experienced by a vehicle using this technology is directly related to how much of the vehicles' operation time is spent in Atkinson mode. This means vehicles that typically operate at a high load, like a truck towing a trailer, will spend more time in the Otto mode and less time in the Atkinson cycle mode, and will achieve a lower overall efficiency improvement over a traditional Atkinson engine that operates full-time in the Atkinson cycle. As a result, manufacturers will try to use this type of engine in conjunction with other type of technologies that reduce engine load, which allows the engine to operate more frequently in Atkinson cycle mode. For example, manufacturers could reduce parasitic losses by incorporating more efficient accessory technologies, or reducing overall vehicle mass and aerodynamic drag. These technologies are enablers for Atkinson-mode engines. When these types of technologies are adopted, it reduces the parasitic losses and, in turn, reduces the time the engine is in high load region. An example of an Atkinson-mode engine is the [text forthcoming].

The last type of Atkinson-type engine, the Atkinson-enabled engine, can be characterized by primarily running the Otto cycle, but can achieve Atkinson-mode using variable valve timing technology (VVT). Some engines use changes in VVT on the intake side to enable Atkinson Cycle in low load, low speed operation, like city driving. These types of engines are typically used in applications that generally require higher specific power such that it would be infeasible to use Atkinson-mode engines or Atkinson engines. These vehicles tend to have higher load demands due to towing requirements, payload requirements, greater aerodynamic drag from larger frontal areas, greater tire rolling resistance from larger tires and higher driveline losses from four-wheel drive or all-wheel drive (*e.g.*, SUVs and pickup trucks). These higher load

[698] Specific Power is the maximum power produced per displacement typically in units of hp/L or kw/L.
[699] Toyota. "Under the Hood of the All-new Toyota Prius." Oct. 13, 2015. Available at https://global.toyota/en/detail/9827044. Last accessed Nov. 22, 2019.
[700] Matsuo, S., Ikeda, E., Ito, Y., and Nishiura, H., "The New Toyota Inline 4 Cylinder 1.8L ESTEC 2ZR-FXE Gasoline Engine for Hybrid Car," SAE Technical Paper 2016-01-0684, 2016, https://doi.org/10.4271/2016-01-0684.

demands tend to push these engines more frequently to the less efficient region of the engine map and limit the level of Atkinson operation. An example of the Atkinson-enabled engine is the [text forthcoming].

EPA developed two engine maps representing non-hybrid Atkinson engines to support the 2016 Draft TAR, Proposed Determination, and first Final Determination.[701] Referred to as ATK and ATK2, the engines represented a current non-hybrid Atkinson cycle engine based on the 2.0L 2014 Mazda SkyActiv-G (ATK) engine, and a future Atkinson engine concept based on the Mazda engines, but adding cooled EGR, cylinder deactivation, and an increased compression ratio (14:1) developed for full vehicle modeling and simulation (ATK2). The agencies adopted EPA's high compression ratio (HCR) engine maps as Eng24 and Eng25, which corresponded to HCR1 and HCR2 in the CAFE modeling.

The Alliance had provided significant comments on the 2016 Draft TAR regarding the engine maps for HCR engines.[702] The Alliance detailed concerns regarding the feasibility and effectiveness of Eng24 (HCR1) and Eng25 (HCR2). Many of the comments on the 2016 Draft TAR noted that the modeling projected an implausible rapid fleet penetration for these technologies, and overestimated effectiveness. The overestimation was due largely to modeling with high-octane fuel and the theoretical addition of other technologies like cEGR and cylinder deactivation (DEAC). In contrast, other commenters had stated that EPA's work on the future Atkinson concept "has shown this pathway to be a promising alternative way to match the levels of improvement from a 27-bar BMEP turbocharged engine," and that "it is prudent to assume that the robust body of evidence EPA is putting together based on benchmarking and modeling data is a reasonable assessment of the technology's potential."[703]

Commented [A239]: **REVISE:** Compliance testing for CAFE purposes uses high-octane fuel.

For the NPRM analysis, the agencies included EPA's engine maps. The agencies allowed HCR1 to be applied only for a few manufacturers that indicated they would pursue this technology pathway versus alternative pathways, such as downsized turbocharged engines. The agencies were also careful to maintain vehicle performance and utility attributes when considering the application of Atkinson-type technologies. Current Atkinson capable engines have incorporated other technologies to reduce load in order to maximize time in Atkinson operation. This includes increased compression ratio, SGDI, improved accessories, addition of friction reduction technologies, and other technologies that reduce engine load. Although modern improvements to engines have allowed Atkinson operation to occur more often (because

[701] [Docket ID] Draft Technical Assessment Report (TAR), Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025; at p. 5-282. [Docket ID] Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation; pp. 22 & A-7. [Docket ID] Final Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, Response to Comments; pp. 29 & 52.

[702] Alliance of Automobile Manufacturers, Alliance of Automobile Manufacturers Comments on Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025 (EPA-420-D-16-900, July 2016), at 45 (Sept. 26, 2016), Docket ID EPA-HQ-OAR-2015-0827-4089 and NHTSA-2016-0068-0072.

[703] Union of Concerned Scientists Comments Concerning the Draft Technical Assessment Report for the Mid-term Evaluation of Model Year 2022-2025 Light-duty Vehicle Greenhouse Gas Emissions and Fuel Economy Standards, at 10-11.

of lower engine loads) for passenger cars, larger vehicles capable of carrying more cargo and occupants, and towing larger and heavier trailers, have more limited potential Atkinson operation. Those adoption features are discussed further in Section [HCR Adoption Features], below.

The agencies excluded the HCR2 concept engine from the central analysis for several reasons articulated in the NPRM. First, the concept was not subjected to validation to assess its technical feasibility. ~~It was only modeled with high octane Tier 2 fuel and its capability to operate on regular octane Tier 3 fuel was never assessed.~~ As discussed further above and in Section [Fuel Octane], fuel octane affects engine durability, performance, drivability, and noise, vibration and harshness. Assumptions about compression ratio, EGR rates, and use of cylinder deactivation were not adequately validated. PRIA Chapter 6.3.2.2.20.18 discussed many questions about its practicability as specified, especially in high load, low engine speed operating conditions. There also has been no observable physical demonstration of the technology assumptions. Many manufacturer engine experts questioned its technical feasibility and commercial practicability during the model years covered by the rulemaking. Stakeholders like the Alliance had previously asked for the engine to be removed from the rulemaking analyses until the performance could be validated with engine hardware. For these reasons, the agencies considered the HCR2 engine too speculative to include in the NPRM central analysis. However, the agencies did provide a sensitivity analysis that included the HCR2 engine.

Commented [A240]: DELETE: This is not factually correct. As described in comments above, EPA engine maps consider BOTH Tier 2 fuel (for certification) and Tier 3 fuel (for calibration, real world fuel consumption and emissions)

Commented [A241]: REVISE: Suggest that the sensitivity results be presented here. SPECIFICALLY, a major point raised about the ANL engine analysis is that the absolute efficiency of the modeled IAV engines is too low, and when combined with the benchmarked EPA engine maps (HCR1, HCR2) the incremental effectiveness to HCR1 and HCR2 is too high.

They do point out previously here in the preamble that isn't an issue, so long as the relative effectiveness is correct. However, when a group of engine maps with an offset base efficiency (like the IAV maps) is intermixed with correct maps, it introduces a relative offset in effectiveness – which is exactly the problem we see with the ANL analysis.

We would expect to see, in the sensitivity analysis, a substantial uptake in HCR2 because of the under-estimated baseline engine efficiency (assuming relatively unconstrained allowance of HCR2). However, we are not sure if any further adjustments were made to the HCR2 technology which would result in more realistic incremental effectiveness.

[Text Forthcoming].

(4) HEV Atkinson Cycle Engines

Three types of Atkinson technology were discussed in the previous section. HEV Atkinson cycle engines fall in the first category, operating solely or primarily in Atkinson mode, supported by an electric drive.

Engine map 26 is the model of the HEV/PHEV Atkinson cycle engine used for the NPRM analysis. The engine was based on ANL's Advanced Mobility Technology Laboratory (AMTL) 2010 Toyota Prius test data and published literature.[704] ANL's AMTL is continuously involved in research and testing of advanced technologies, especially in areas of electrification, and has a large existing database of test data from advanced technology vehicles.[705] As a result of ANL's continued research, a 2017 Toyota Prius was characterized for an independent project. ANL updated the HEV Atkinson cycle engine using the new Prius data to reflect the 41% thermal efficiency of the new 2017 system.[706]

[704] "2010 Toyota Prius." http://www.anl.gov/energy-systems/group/downloadable-dynamometer-database/hybrid-electric-vehicles/2010-toyota-prius. Last accessed April, 2018.
[705] ANL AMTL Downloadable Dynamometer Database (D3). https://www.anl.gov/es/downloadable-dynamometer-database. Last accessed Dec. 05, 2019.
[706] Carney, D. "Toyota unveils more new gasoline ICEs with 40% thermal efficiency." SAE. April 4, 2018. https://www.sae.org/news/2018/04/toyota-unveils-more-new-gasoline-ices-with-40-thermal-efficiency. Last accessed Dec. 5, 2019.

The final rule analysis used the same engine as the NPRM but updated the thermal efficiency. The electrification technology groups that used Eng26 include powersplit hybrid vehicles (SHEVPS) and plug-in powersplit hybrid vehicles (PHEV20/50).

Commented [A242]: **REVISE:** It's not clear what this means. Is it the same engine map,but with some BSFC offset added in to obtain 41% peak? Why would this approach be used?

(5) Advanced Cylinder Deactivation Technologies

Advanced cylinder deactivation systems (ADEAC), also known as rolling or dynamic cylinder deactivation systems, allow a further degree of cylinder deactivation than the base DEAC. ADEAC allows the engine to vary the percentage of cylinders deactivated and the sequence in which cylinders are deactivated, essentially providing "displacement on demand" for low load operations.

ADEAC systems may be integrated into the valvetrains with moderate modifications on OHV engines. However, while the ADEAC operating concept remains the same on DOHC engines, the valvetrain hardware configuration is very different, and application on DOHC engines is projected to be more costly per cylinder due to the valvetrain differences.

Some preproduction 8-cylinder OHV prototype vehicles were briefly evaluated for this analysis, but no production versions of the technology have been studied.[707] For ADEAC fuel consumption effectiveness values, no engine map was available at the time of the NPRM analysis. Accordingly, the agencies took the effectiveness values as predicted by full vehicle simulations of a DEAC engine with SGDI, VVL, and VVT, and added 3% or 6% respectively for I-4 engines and V-6 or V-8 engines, and cross-referenced CBI data to quality check this approach. The agencies noted two potential approaches to including advanced cylinder deactivation in the full-scale ANL simulation modeling analysis for the final rule. First, the agencies proposed using IAV Eng25a, which was developed to capture the maximum benefits of advanced cylinder deactivation with several constraints that could include emissions, cold start, NVH, and durability. Second, the agencies proposed using a technique developed by ANL in coordination with NHTSA to split the overall engine data into individual cylinder data and compute overall torque and the fuel consumption rate by accounting for whether each cylinder is active or inactive. The agencies sought comment on using either approach in the final rule analysis to capture best the benefits of advanced cylinder deactivation.

CARB, ICCT, Meszler Engineering Services, HDS, and UCS provided a mixed set of comments on numerous aspects of ADEAC in the NPRM analysis.[708] Stakeholders provided comments regarding the description of the ADEAC, the adoption features of the ADEAC, the effectiveness of the ADEAC, and the costs of the ADEAC.

The agencies discussed assumptions and effectiveness for the ADEAC package in the NPRM preamble.[709] In the NPRM analysis, the agencies took the effectiveness values based on

[707] EPA, 2018. "Benchmarking and Characterization of a Full Continuous Cylinder Deactivation System." Presented at the SAE World Congress, April 10-12, 2018. Retrieved from https://www.regulations.gov/document?D=EPA-HQOAR-2018-0283-0029.
[708] CARB comment; ICCT comment; Meszler comment; Duleep Comment; UCS comment.
[709] [Reference Preamble location for ADEAC.]

data from CBI. The initial review of this technology was based on technical publication that used a MY 2010 engine design that had incorporated a SOHC VVT basic engine.[710] Since then, many of these base engine technologies have been updated to include other engine technologies like SGDI and DEAC. The MY2017 baseline fleet reflects technology updates such as SGDI and DEAC that could adopt ADEAC incrementally in the final rule analysis. The cost and effectiveness for ADEAC reflects the baseline engine. The 2015 NAS Committee estimated an 0.7% fuel consumption improvement for adoption of cylinder deactivation for V6s and V8s engines.[711,712]

The agencies requested comments on alternative methods to evaluate ADEAC for effectiveness but received no comments regarding either approach mentioned in the NPRM. For the final rule analysis, the agencies used effectiveness values as predicted by full vehicle simulations of a DEAC engine with SGDI, VVL, and VVT, and added 3% or 6% respectively for I-4 engines and V-6 or V-8 engines for the naturally aspirated engines. Effectiveness for turbocharged engines used 1.5% and 3% values, as predicted by full vehicle simulation of a TURBOD engine for I4 and V6/V8, respectively. Without sufficient data to simulate ADEAC, both the IAV and ANL methodologies described in the NPRM provided questionable estimates for ADEAC. These errors would have propagated across other technology combinations in the analysis. The estimates used for ADEAC and TURBOD for the final rule analysis are also in line with EPA estimates discussed in their SAE technical publications.[713]

HDS commented on a need to describe ADEAC technology better: "The 2018 analysis also utilized Advanced Cylinder Deactivation in its analysis but the package components were not completely explained in the PRIA."[714] For the final rule analysis, a complete description of the ADEAC technology used can be found in [Paragraph X in the RIA].

For the final rule analysis, the agencies used the same effectiveness values for ADEAC applied to naturally aspirated engines as in the NPRM, and incorporated estimated effectiveness values for TURBOAD to represent ADEAC on downsized turbocharged engines.

(6) Miller Cycle Engines

In the proposed rule, the agencies provided two engine maps representative of Miller Cycle and Eboost engines with 48V battery systems. The Miller Cycle engine (Eng23b) and Miller Cycle engine with Eboost (Eng23c) specifications were provided in NPRM PRIA but

[710] Wilcutts, M., Switkes, J., Shost, M., and Tripathi, A., "Design and Benefits of Dynamic Skip Fire Strategies for Cylinder Deactivated Engines," SAE Int. J. Engines 6(1):278-288, 2013, available at https://doi.org/10.4271/2013-01-0359. Eisazadeh-Far, K. and Younkins, M., "Fuel Economy Gains through Dynamic-Skip-Fire in Spark Ignition Engines," SAE Technical Paper 2016-01-0672, 2016, available at https://doi.org/10.4271/2016-01-0672.
[711] Applied after VVT and VVL.
[712] Applied before VVT and VVL.
[713] Kargul, J., Stuhldreher, M., Barba, D., Schenk, C. et al., "Benchmarking a 2018 Toyota Camry 2.5-Liter Atkinson Cycle Engine with Cooled-EGR," SAE Int. J. Adv. & Curr. Prac. in Mobility 1(2):601-638, 2019, https://doi.org/10.4271/2019-01-0249 at pp. 19-21.
[714] [HDS Comment]

were not used in the NPRM analysis,[715] although the agencies sought comment on the specifications used for the modeling.

Roush on behalf of CARB, ICCT, Meszler Engineering on behalf NRDC, HD Systems and UCS, commented that the agencies did not consider the combination of turbocharging and Miller Cycle.[716] Specifically, Roush argued that the agencies' omission of an engine that utilizes a combination of turbocharging and Miller Cycle is unreasonable because it is already in production, specifically on the VW 2.0L EA888 Gen3B – DI. Roush stated this omission would limit the effectiveness for turbocharged engines and cause the adoption of more expensive solutions, thereby overstating the cost to achieve target fuel economy levels. Similarly, Roush pointed to the omission of an engine that uses a variable geometry turbocharger as an error in the agencies' vehicle modeling; Roush pointed to VW's EA211 TSI Evo engine available in Europe in 2017 as an example of an engine in production that enables cost-effective Miller Cycle applications.

In response to these comments, the agencies added and used both Miller Cycle type engines and Miller Cycle engines with electric assist for the final rule analysis. Discussed earlier in this section, the agencies developed engine maps for additional combinations of technologies for the final rule, including engine maps that became available after the NPRM analysis was completed but before the NPRM was published. For the final analysis, the agencies have included a Miller Cycle engine Eng23b (VTG) to be selected as another engine technology. The specification of this engine is discussed in PRIA Chapter 6.3.2.2.20.20.2.2 and the costs are based on the 2015 NAS estimates for this technology.

(7) Variable Compression Ratio Engines

Engines using variable compression ratio (VCR) technology appear to be at a production intent stage of development but also appear to be targeted primarily towards limited production, high performance and very high BMEP (27-30 bar) applications. Variable compression ratio engines work by changing the length of the piston stroke of the engine to operate at a more optimal compression ratio and improve thermal efficiency over the full range of engine operating conditions.

Commented [A243]: **REVISE:** These engines are in production, and have been for a year.

A few manufacturers and suppliers provided information about VCR technologies, and several design concepts were reviewed that could achieve a similar functional outcome. In addition to design concept differences, intellectual property ownership complicates the ability of the agencies to define a VCR hardware system that could be widely adopted across the industry.

For the NPRM analysis, VCR engines were included in the technology tree, but VCR was not actively used in the NPRM simulation. In addition, the agencies provided specifications of a VCR engine (Eng26a) in the PRIA for review and comment.[717]

[715] NPRM PRIA at p.307-09.
[716] NHTSA-2018-0067-11985, HD systems at p. []; ICCT at p. []; NRDC at p. []; HD Systems at p. [].
[717] NPRM PRIA at pp. 304-06.

The Alliance commented in support of the exclusion of variable compression ratio engines from the analysis, stating that the technology is still in early development, and too speculative to be included at this time. The Alliance also stated that the technology is unlikely to attain significant penetration in the MY 2026 timeframe due to intellectual property protection associated with early implementations and its likely application primarily to high-performance vehicles. The Alliance also cited the technology's price as a potential barrier to adoption.[718] Similarly, Ford commented that VCR technology "is likely to be adopted only for premium / limited-market vehicles in the near future. We also agree that intellectual property protections on early implementations will further inhibit significant fleet penetration. Incorporation of VCR requires a new or highly modified engine architecture, necessitating major investment from both the engineering and manufacturing standpoints. Sharing / commonality across engine families would be greatly limited."[719,720] Similarly, other automakers commented on a confidential basis that several main hurdles prevented them from employing VCR engines, including the complexity of VCR engines and the associated cost of those complex parts.

UCS commented that the agencies did not consider VCR engine technologies in the NPRM analyses.[721] They stated that the technology was not modeled, nor was it incorporated into the CAFE model. UCS argued that Nissan's VC-Turbo engine is part of a strategy to improve fuel efficiency for Nissan's luxury vehicles by 30-35 percent over previous models, which would be enough to exceed the vehicle's regulatory targets without any credits. UCS concluded that given VCR technology is being put into production in a high-volume vehicle, there is no reason for the agencies to exclude its adoption.

The agencies agreed with comments to include VCR engine technologies in the final rule analysis and on further technical consideration, the agencies have added a VCR engine to the engine technologies list manufacturers could adopt. However, the agencies limited the adoption of the VCR engine technology to Nissan only. VCR engines are complex, costly by design, and synergetic with mainstream technologies like downsize turbocharging, making it unlikely that a manufacturer that has already started down an incongruent technology path would adopt VCR technology.

(8) Diesel Engines

Diesel engines have several characteristics that result in superior fuel efficiency over traditional gasoline engines, including reduced pumping losses due to lack of (or greatly reduced) throttling, high pressure direct injection of fuel, a combustion cycle that operates at a higher compression ratio, and a very lean air/fuel mixture relative to an equivalent-performance gasoline engine.[722] However, diesel technologies requires additional enablers, such as a NO_x

[718] NHTSA-2018-0067-12073 ("At least one source also indicates a steep price to this technology—"at least $3,000 more to produce than a standard 16-valve double-overhead-camshaft four- cylinder.").
[719] NHTSA-2018-0067-11928.
[720] [Ford's citation.]
[721] [UCS comment.]
[722] Diesel cycle is also a four-stroke cycle like the Otto Cycle, except in the Intake stroke no fuel is injected and fuel is injected late in the compression stroke at higher pressure and temperature.

adsorption catalyst system or a urea/ammonia selective catalytic reduction system, for control of NO_x emissions.

For the NPRM, the agencies modeled one diesel engine, represented by Eng17,[723] which was termed "ADSL" in the CAFE modeling. DSLI, a more advanced diesel engine, represented a 4.5% effectiveness improvements over ADSL.

CARB commented that diesel technologies are essentially locked out of being selected in the CAFE model because of the high cost.[724] They state that diesel technology is only selected in rare instances.

The agencies agree that diesel technology is rarely selected. The technologies required to meet diesel emissions standards are costlier compared to gasoline technologies, particularly in the rulemaking timeframe. For example, the 2015 NAS determined that in the current market, "vehicles with diesel engines are priced an average of more than $4000 more than comparably equipped gasoline vehicles."[725] Furthermore, 2015 NAS stated that the "Carbon Penalty" makes it harder for manufactures to meet CO_2 standards because of the higher carbon density in the diesel fuel compared to gasoline that results in higher CO_2 per gallon.[726] In addition, the market for diesel vehicles has stagnated at around 1% for many years after it peaked at 5.9% in 1981, according to the EPA Trends Report.[727] We believe that the modeled cost of diesel engines appropriately prevents their widespread adoption in the analysis.

UCS commented that the agencies restricted cylinder deactivation technologies to only naturally aspirated gasoline engines.[728] In response to this and other comments, the agencies have allowed diesel engines to adopt ADEAC for this final rule analysis. These engines were designated as DSLIAD to represent diesel engines with ADEAC, and represented a 7.5% effectiveness improvement on top of DSLI. This effectiveness improvement of ADEAC on diesel engines is based on the review of technical publications discussed earlier in the ADEAC paragraph.

(9) Alternative Fuel Engines

CNG engines use compressed natural gas as a fuel source. The fuel storage and supply systems for these engines differ tremendously from gasoline, diesel, and flex fuel vehicles. CNG engines were a baseline-only technology and were not applied to any vehicle that was not already CNG-based in NHTSA's analysis, per EPCA/EISA's restrictions on considering

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[723] Docket ID NHTSA-2018-0067-1972. NPRM PRIA at p. 295.
[724] Docket ID NHTSA-2018-0067-11873. CARB at 108.
[725] [2015 NAS citation at diesel cost section.]
[726] 2015 NAS Findings 3.3 and 3.4 at p. 120.
[727] EPA, "The 2018 EPA Automotive Trends Report." March 2019. EPA-420-R-19-002. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100W5C2.PDF?Dockey=P100W5C2.PDF at pp.5 & 6. Last accessed December 16, 2019.
[728] Docket ID NHTSA-2018-0067-12039, at p. 3.

dedicated alternative fueled vehicles to set fuel economy standards.[729,730] However, for the EPA program the agencies allowed any vehicle to adopt CNG engines. The NPRM MY 2016 analysis fleet did not include any dedicated CNG vehicles to simulate in the CAFE Model.

In addition, for the NPRM and this final rule analysis, NHTSA modified the CAFE model to include the specific provisions related to AFVs under the CO_2 standards. In particular, the CAFE model now carries a full representation of the production multipliers related to electric vehicles, fuel cell vehicles, plug-in hybrids, and CNG vehicles, all of which vary by year through MY 2021.

(10) Emerging Gasoline Engine Technologies

Manufacturers, suppliers, and researchers continue to create a diverse set of fuel economy technologies, some of which are still in the early stages of the development and commercialization process. Due to uncertainties in the cost and capabilities of emerging technologies, some new and pre- production technologies are not a part of the CAFE model simulation. As discussed throughout this section and in [Section Technology Effectiveness], the agencies declined to include technologies in the analysis where the agencies did not believe those technologies would be feasible in the rulemaking timeframe, or the agencies did not have appropriate data upon which to generate an estimate of how effective the technology is that could be applied across the ten vehicle classes. Evaluating and benchmarking promising fuel economy technologies as they enter production-intent stages of development continues to be a priority as commercial development matures.

UCS and ICCT commented that the agencies should consider novel engine designs.[731] Specifically, ICCT stated that the agencies should consider a more advanced HCR technology called HCCI (similar to Mazda's Skyactiv-X) by estimating efficiency and cost to EPA's process that assigned effectiveness estimates using LPM. They stated that "the agencies developed estimates for ADEAC in the NPRM and the associated modeling even without conclusive and independently verifiable effectiveness."

In response to the comments, a number of technologies have been added for the final rule analysis, and adoption features have been refined accordingly, as discussed further in [Section Engine Adoption Features]. The new technologies include Atkinson engine technology allowed with P2 HEV, PHEV range reduced from 30 miles to 20 miles, updated 48v system for BISG/CISG, mass reduction—allow up to approximately 20 percent of curb weight and revise the mass reduction increments between zero and 20 percent, new High Compression Ratio

[729] NHTSA's provisions for dedicated alternative fuel vehicles in 49 U.S.C. 32905(a) state that the fuel economy of any dedicated automobile manufactured after 1992 shall be measured based on the fuel content of the alternative fuel used to operate the automobile. A gallon of liquid alternative fuel used to operate a dedicated automobile is deemed to contain 0.15 gallon of fuel. Under EPCA, for dedicated alternative fuel vehicles, there are no limits or phase-out for this special fuel economy calculation, unlike for duel-fueled vehicles, as discussed below.
[730] EPA's provisions for dedicated alternative fuel vehicles that are able to run on compressed natural gas (CNG) currently are eligible for an advanced technology multiplier credit for MYs 2017-2021.
[731] ICCT, Full Comments Summary. Docket No. NHTSA-2018-0067-117411, at I-17 to I-19.
UCS, Comment. Docket No. NHTSA-2018-0067-12039, at pp. 6 & 7.

engine, Variable Compression Ratio engine, Variable Geometry Turbo engine, Variable Geometry Turbo with Electric Assist engine, Diesel with Advanced Cylinder Deactivation engine, Turbo with Cylinder Deactivation engine, Diesel with Manual Transmission, Diesel with Start Stop, PHEV-Turbo with 20 mile range, and PHEV-Turbo with 50 mile range.

The agencies also disagree with ICCT's comment that ADEAC was developed without conclusive and independently verifiable effectiveness. Estimates for ADEAC were based on CBI data from both manufacturers and suppliers, technical publications, and engineering judgement. The agencies benchmarked the first prototype of skip-fire and discussed extensive potential application of it for other engine technologies.

The agencies also believe that the technology associated with Mazda SkyActiv-X has been mischaracterized by ICCT and other commenters, and declined to include a specific representation of the SkyActiv-X family of technologies in the analysis for two reasons. The engine known as Skyactiv-X is characterized by Mazda as a unique Spark Plug Controlled Compression Ignition (SPCCI) technology, 2-liter displacement, 4-cylinder engine with mechanical compression ratio of 16.3:1 operating on 95 RON fuel (91 AKI) with a mild hybrid system.[732] The NPRM and this final rule analysis may not have the exact technology combination associated with this vehicle, but the analysis does include technologies that are representative of them, that could enable the benefits employed by the Mazda engine. A mild hybrid system is available for adoption in both the NPRM and this final rule analysis.

Second, the effectiveness associated with this engine was from European test cycles and cannot be compared for U.S. application. European compliance tests are significantly different than those in the U.S., especially when it comes to fuel type and test cycles. Any effectiveness data provided for this engine or any non-U.S. engine cannot be used for U.S. vehicle application with adjustment for fuel and emissions. For example, the higher-octane fuel used in Europe enables engines to operate at higher compression ratios, like this engine.

The agencies believe that with the aforementioned technology additions for the final rule, the analysis reasonably represents the suite of engine technologies that could be available in the rulemaking time frame. Manufacturers, suppliers, and researchers continue to create a diverse set of fuel economy technologies. However, due to the uncertainties in the cost, manufacturing, and intellectual property concerns like those identified by commenters, the agencies did not consider prototype technologies in the final rule analysis.

(11) Engine Lubrication and Friction Reduction Technologies

Low-friction lubricants including low viscosity and advanced low-friction lubricant oils are now available, and widely used. Manufacturers may make engine changes and conduct

[732] Mazda Press Release. "Revolutionary Mazda Skyactiv-x engine details confirmed sales start." May 6, 2019. https://www.mazda-press.com/eu/news/2019/revolutionary-mazda-skyactiv-x-engine-details-confirmed-as-sales-start/. Last accessed Dec, 11, 2019.

durability testing to accommodate the lubricants. The level of low-friction lubricants exceeded 85% penetration in the MY 2016 fleet.[733]

Reduction of engine friction can be achieved through low-tension piston rings, roller cam followers, improved material coatings, more optimal thermal management, piston surface treatments, and other improvements in the design of engine components and subsystems that improve efficient engine operation.

Manufacturers have already widely adopted both lubrication and friction reduction technologies. Previous agency analysis considered these improvements in combination as Improved Low Friction Lubricants and Engine Friction Reduction (LUBEFR). The NPRM analysis included advanced engine maps that already assume application of low-friction lubricants and engine friction reduction technologies, and therefore additional levels of friction reduction were not considered.

Meszler Engineering on behalf of NRDC commented that "the NPRM CAFE model no longer considers advanced lubricants and evolutionary friction reduction (LUBEFR) to be adoptable. As a result, no fuel efficiency improvement credits are available. Engine friction reduction is an ongoing evolutionary process that should generate benefits on the order of 5 percent or so increase in fuel economy over a multiyear forecast period, with costs totaling approximately $100. Moreover, the technology is a benefit of ongoing industry research and evolutionary engine improvements so that it is easily 'adoptable' and deployed throughout the fleet. Accordingly, NHTSA should revise the NPRM CAFE model to reinstate the ability to adopt evolutionary friction reduction technology."[734]

The agencies disagree with Meszler that a five percent fuel economy improvement attributable to lubricants and evolutionary friction reduction is continuously feasible. The MY 2017 baseline vehicles have incorporated many technologies like low viscosity engine oil, integrated exhaust manifold for faster oil warmup, and internal component friction reduction.[735,736,737] The LUB and EFR technologies are a legacy of the existing rulemaking work going back to the 2010 CAFE and CO_2 rule for MY 2012 to MY 2016.[738] We believe that many of these technologies have been incorporated in many of the engines in the baseline fleet, and therefore the engine maps used for the NPRM and final rule analysis incorporated them as well. Furthermore, manufactures have raised concerns over issues with further decreasing oil

[733] [NPRM market data file.]
[734] Meszler Engineering. Docket ID NHTSA-2018-0067-11723, at p. 32.
[735] Wards Auto. "Infiniti's Brilliantly Downsized V-6 Turbo Shines." July 11, 2017. Available at https://www.wardsauto.com/print/engines/infiniti-s-brilliantly-downsized-v-6-turbo-shines. Last accessed Dec. 11, 2019. Nissan Motor Corp. "Mirror Bore Coating". Available at https://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/mirror_bore_coating.html. Last accessed Dec 11, 2019.
[736] Toyota's 2AR-FE I4 and 2GR-FE V6 use 0-W20.
[737] Audi Media Center. "Efficiency and driving pleasure: innovative V engines at Audi." Available at https://www.audi-mediacenter.com/en/techday-on-combustion-engine-technology-8738/efficiency-and-driving-pleasure-innovative-v-engines-at-audi-8748. Last accessed Dec.11, 2019.
[738] 75 FR 25373.

viscosity; specifically, manufacturers have articulated concerns that damage caused by low speed pre-ignition (LSPI)[739] can damage an engine.[740, 741, 742]

In response to the comment that engine friction reduction technology is evolutionary technology, the agencies introduced one level of friction reduction (EFR) for the final rule analysis. We estimated a 1.4% effectiveness for this type of technology based on the 2015 NAS report assessment of further improvements in lubrication and friction.[743]

d) How we assign engine technologies to the baseline fleet

Manufacturers have made significant improvements in fuel economy and CO_2 emissions reductions since the MY 2012 rulemaking analysis.[744,745] The agencies expended substantial effort to update the analysis fleet from the model year 2016 representative fleet used for the NPRM to a model year 2017 analysis fleet used for this final rulemaking to capture the technologies manufacturers have used to increase their fleet's fuel economy and CO_2 emissions performance. Detailed discussion of the model year 2017 fleet development and application can be found in Section [MY 2017 Fleet Discussion Section]. The agencies extensively updated the new model year 2017 fleet engine technologies using available manufacturer final model year CAFE compliance submissions to the agencies, as well as manufacturer press release specifications, agency-sponsored vehicle benchmarking studies, review of available technical publications, and through manufacturer CBI.[746]

The data for each manufacturer was used to determine which platforms shared engines and to establish the leader-follower relationships between vehicles. Within each manufacturer's fleet, engines were assigned unique identification designations based on configuration, and technologies applied, along with other characteristics. The data were also used to identify the most similar engine among the Autonomie engine models, as discussed in Section [xx].

Just like the real-world vehicle variants, the CAFE model considers differences between each vehicle like base performance and higher performance levels. For example, the 2017 Ford

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[739] LSPI is an abnormal combustion event in which the fuel-air mixture ignites before intended, causing excessive pressures inside the engine's cylinders. In mild cases, this can cause engine noise, but when severe enough, LSPI can cause engine damage. There are several factors that contribute to LSPI, of which lubricating oil has been observed to be one.

[740] Motor Magazine. "Will ILSAC GF-6 Ever Be Approved?" Nov. 20, 2018. Available at http://newsletter.motor.com/2018/20181120/ID_Infineum_ILSAC_GF-6.html. Last accessed Dec 11, 2019.

[741] Chevron. "Low Speed Pre-ignition." Available at https://www.oronite.com/about/news/low-speed-pre-ignition.aspx. Last accessed Dec. 11, 2019.

[742] Elliott, L., Sztenderowicz, M., Sinha, K., Takeuchi, Y. et al., "Understanding Low Speed Pre-Ignition Phenomena across Turbo-Charged *GDI* Engines and Impact on Future Engine Oil Design." SAE Technical Paper 2015-01-2028, 2015, available at https://doi.org/10.4271/2015-01-2028.

[743] 2015 NAS at pp. 28 & 29.

[744] [Reference EPA 2018 Trends Report.]

[745] FOTW #1108, Nov 18, 2019: Fuel Economy Guide Shows the Number of Conventional Gasoline Vehicle Models Achieving 45 miles per gallon or Greater is Increasing. DOE VTO. Available at https://www.energy.gov/eere/vehicles/articles/fotw-1108-november-18-2019-fuel-economy-guide-shows-number-conventional. Last accessed Nov 18, 2019.

[746] [NPRM Market data file name.]; [NPRM Market data file discussion].

F150 has many variants with different types of engines like the 2.7L Turbocharged V6, 3.3L N.A. V6, 3.5L Turbocharged V6, and 5L N.A. V8. In contrast to the LPM, the CAFE model rosters each variant level and powertrain application individually. This variation is accounted for as engine technologies are assigned in the analysis fleet.

As a result of new information available since publication of the NPRM and comments received to the NPRM, the agencies included additional engine technologies in the compliance analysis, expanding the total number of engine technologies available from 16 to 23. This expansion is a direct result of comments received to the NPRM and further enables the agencies' capabilities to accurately and, realistically, characterize the technologies present on an engine found in the analysis fleet. This collection of technologies represents the best available information the agencies have, at the time of this action, regarding both currently available engine technologies and engine technologies that could be feasible for application to the U.S. fleet during the rulemaking timeframe. The agencies believe this effort has yielded the most technology-rich and accurate analysis fleet utilized by the CAFE model to date.

In some cases, however, it was necessary for the agencies to substitute an engine map that closely represented a suite of engine technologies that were effectively the same, or, based on engineering judgement, were the best available proxy at the time of the analysis. This substitution was necessary, in some cases, where an "exact-match" engine map was not available for application to a specific vehicle and/or vehicle specific engine application. The agencies leveraged a series of engine operating characteristic maps developed by industry suppliers and, in some cases, the agencies themselves, to assign the closest baseline engine map for the analysis.

Commented [A244]: **REVISE:** This is exactly the process that NHTSA has elsewhere suggested above was LESS "rigorous and technically sound"

As discussed in Section [xx], these engine maps provide operational characteristics such as horsepower, torque, or efficiency at a specified point in an engine's operational range. These operational maps are developed based on a given set of engine characteristics and technologies applied to that engine. Engine maps are closely held by vehicle manufacturers and are typically considered intellectual property. As such, vehicle manufacturers are not typically willing provide the operational maps to the agencies, where it would ultimately be in the purview of competitors. In some instances, manufacturer engine maps are published in media such as technical papers or conference presentation materials. However, these publicly available engine maps are, in nearly all instances, void of critical information that would enable their use for meaningful simulation and modeling.

Therefore, the agencies are generally limited to the catalog of engine maps they have developed through contracts and, where possible, in-house which, in turn, yields the need for sound, engineering judgement-based substitution of an engine map as a proxy for an engine application in the marketplace. Unfortunately, this is necessary as the agencies are unable to fund the development of engines maps for every possible engine and technology combination available for sale. However, it is important to note the agencies do have a substantial catalog of engine maps to leverage and continue to fund the development of new maps as new technologies enter the marketplace. Additional information on the agencies' catalog of engine maps used for this this final rulemaking can be found in Section [xx].

Some engine technologies are designated in the CAFE Model as "baseline only" technologies, meaning these are characteristics such as engine configuration, architecture, or a technology that is considered inherent to the fleet for the given model year, an example for the MY 2017 fleet used in this analysis is variable-valve-timing (VVT). Beyond the aforementioned configurations and technology, engine technologies that can be applied to a future engine and, eventually, to a vehicle in the compliance modeling are only available at a vehicle redesign. As such, a vehicle will only adopt a new engine according to the application schedule defined as a CAFE model input.

e) Engine adoption features

Engine adoption features are defined through mechanisms like technology path logic or the application of selection logic, refresh and redesign cycles, and phase-in capacity limits. Most of the technology adoption features from the NPRM have been carried over for the final rule analysis. However, the final rule analysis also included adoption features for the new technologies incorporated in the final rule analysis. For a detailed discussion of CAFE model path logic for the final rule analysis, including technology supersession logic and technology mutual exclusivity logic, please see [CAFE model documentation at S4.5].

Figure VI-10andFigure VI-11 below show the engine technology paths used for the NPRM and this final rule analysis, respectively. The engine technology paths have increased to incorporate new advanced technologies manufacturers could adopt into their fleet.

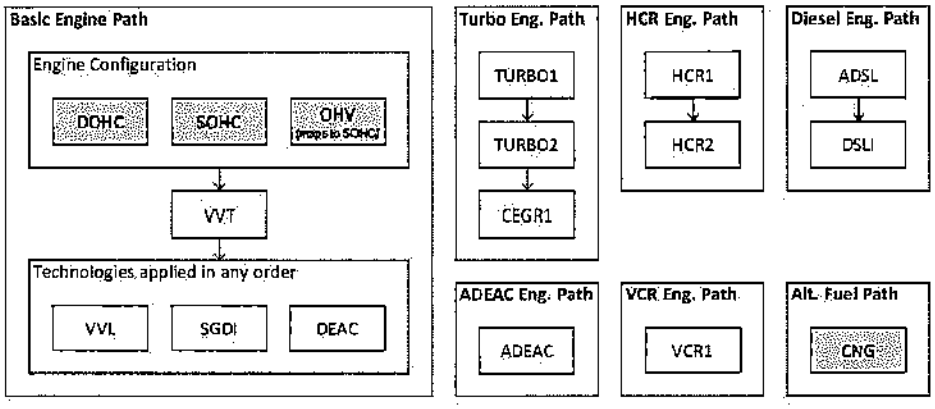

Figure VI-10 - Engine Paths Used for the NPRM Analysis

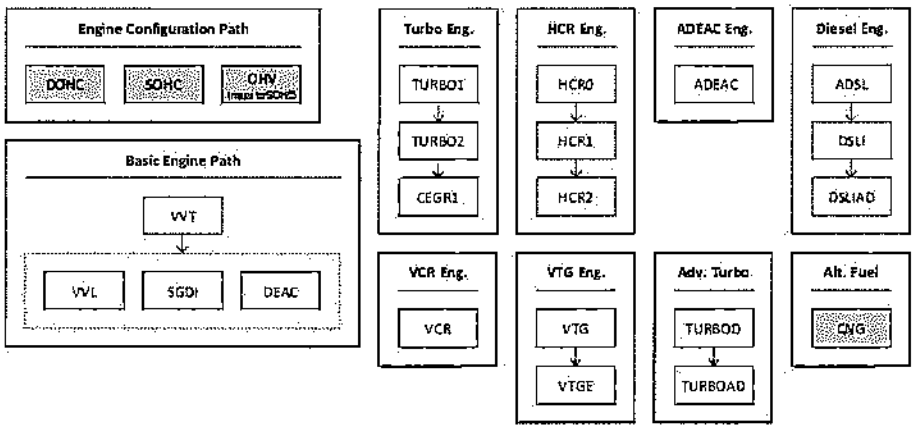

Figure VI-11 – Engine Paths Used for the Final Rule Analysis

Similar to the 2012 final rule for MY2017-MY2025, this final rule analysis also considered real-world limits when the defining the rate at which technologies can be deployed.[747] During the rulemaking timeframe, manufacturers are expected to go through the normal automotive business cycle of redesigning and upgrading their light-duty vehicle products. This allows manufacturers the time needed to incorporate fuel economy improving and CO_2 reducing technologies into their normal business cycle. This is important because it has the potential to avoid the much higher costs that could occur if manufacturers need to add or change technology at times other than their scheduled vehicle redesigns. This time period also provides

[747] 77 FR 62712.

manufacturers the opportunity to plan for compliance using a multi-year time frame, again consistent with normal business practice.

[Section II.G.3.a)] of the NPRM provided substantial discussion of how an "application schedule" is used by the CAFE model to determine when manufacturers are assumed to be able to apply a given technology to a vehicle. The NPRM application schedule for engine technologies is reproduced in Table VI-24Table VI-24, which shows that all of the engine technologies may only be applied (for the first time) during redesign.

Table VI-24 – NPRM CAFE Model Engine Technologies Application Schedule

Technology	Application Level	Application Schedule	Description
SOHC	Engine	Baseline Only	Single Overhead Camshaft Engine
DOHC	Engine	Baseline Only	Double Overhead Camshaft Engine
OHV	Engine	Baseline Only	Overhead Valve Engine (maps to SOHC)
VVT	Engine	Baseline Only	Variable Valve Timing
VVL	Engine	Redesign Only	Variable Valve Lift
SGDI	Engine	Redesign Only	Stoichiometric Gasoline Direct Injection
DEAC	Engine	Redesign Only	Cylinder Deactivation
HCR	Engine	Redesign Only	High Compression Ratio Engine
HCR2	Engine	Redesign Only	High Compression Ratio Engine with DEAC and CEGR
TURBO1	Engine	Redesign Only	Turbocharging and Downsizing, Level 1 (18 bar)
TURBO2	Engine	Redesign Only	Turbocharging and Downsizing, Level 2 (24 bar)
CEGR1	Engine	Redesign Only	Cooled Exhaust Gas Recirculation, Level 1 (24 bar)
ADEAC	Engine	Redesign Only	Advanced Cylinder Deactivation
CNG	Engine	Baseline Only	Compressed Natural Gas Engine
ADSL	Engine	Redesign Only	Advanced Diesel Engine
DSLI	Engine	Redesign Only	Diesel engine improvements

For this final rulemaking action, a similar schedule is employed, and has been updated with information gathered since the NPRM and through comments provided to the agencies.

Table VI-25

Table VI-25 presents the engine technology application schedule used for the final rule CAFE modeling.

Table VI-25 – FRM CAFE Model Engine Technologies Application Schedule

Technology	Application Level	Application Schedule	Description
SOHC	Engine	Baseline Only	Single Overhead Camshaft Engine
DOHC	Engine	Baseline Only	Double Overhead Camshaft Engine
OHV	Engine	Baseline Only	Overhead Valve Engine (maps to SOHC)
EFR	Engine	Redesign Only	Improved Engine Friction Reduction
VVT	Engine	Redesign Only	Variable Valve Timing
VVL	Engine	Redesign Only	Variable Valve Lift
SGDI	Engine	Redesign Only	Stoichiometric Gasoline Direct Injection
DEAC	Engine	Redesign Only	Cylinder Deactivation

TURBO1	Engine	Redesign Only	Turbocharging and Downsizing, Level 1
TURBO2	Engine	Redesign Only	Turbocharging and Downsizing, Level 2
CEGR1	Engine	Redesign Only	Cooled Exhaust Gas Recirculation, Level 1
ADEAC	Engine	Redesign Only	Advanced Cylinder Deactivation
HCR0	Engine	Redesign Only	High Compression Ratio Engine, Level 0
HCR1	Engine	Redesign Only	High Compression Ratio Engine, Level 1
HCR2	Engine	Redesign Only	High Compression Ratio Engine, Level 2
VCR	Engine	Redesign Only	Variable Compression Ratio Engine
VTG	Engine	Redesign Only	Variable Turbo Geometry
VTGE	Engine	Redesign Only	Variable Turbo Geometry (Electric)
TURBOD	Engine	Redesign Only	Turbocharging and Downsizing with DEAC
TURBOAD	Engine	Redesign Only	Turbocharging and Downsizing with ADEAC
ADSL	Engine	Redesign Only	Advanced Diesel
DSLI	Engine	Redesign Only	Diesel Engine Improvements
DSLIAD	Engine	Redesign Only	Diesel Engine Improvements with ADEAC
CNG	Engine	Baseline Only	Compressed Natural Gas Engine

Fuel economy improving and CO_2 reducing technologies for vehicle applications vary widely in function, cost, effectiveness, and availability. Some of these attributes, like cost and availability, vary from year to year. New technologies often take several years to become available across the entire market. The agencies use phase-in caps to manage the maximum rate that the CAFE model can apply new technologies. Phase-in caps are intended to function as a proxy for a number of real-world limitations in deploying new technologies in the auto industry. These limitations can include but are not limited to, engineering resources at the OEM or supplier level, restrictions on intellectual property that limit deployment, and/or limitations in material or component supply as a market for a new technology develops. Without phase-in caps, the model may apply technologies at rates that are not representative of what the industry is actually capable of producing, which would suggest that more stringent standards might be feasible than actually would be. Table VI-26 and Table VI-27 below shows the phase-in caps between the NPRM and this final rule analysis, respectively.

Most engine technologies are available at a rate of 100% in MY2017 for the final rule analysis. Some advanced technologies that have been recently introduced for one or two vehicle models are phased in at lower rates. Technologies such as ADEAC and TURBOD are phase in at rates that represent manufacturers' adoption capability and typically have complementary effectiveness compared to other advanced technologies. These lower phase-in caps also represent intellectual property and functional performance concerns.

Table VI-26 - NPRM CAFE Model Engine Phase-in Caps

Name	Technology Description	Technology Pathway	Phase-in Cap	Phase-in Start Year
VVT	Variable Valve Timing	Basic Engine	100%	2000
VVL	Variable Valve Lift	Basic Engine	100%	2000
SGDI	Stoichiometric Gasoline Direct Injection	Basic Engine	100%	2000
DEAC	Cylinder Deactivation	Basic Engine	100%	2004

TURBO1	Turbocharging and Downsizing, Level 1	Turbocharged Engine	100%	2004
TURBO2	Turbocharging and Downsizing, Level 2	Turbocharged Engine	100%	2010
CEGR1	Cooled Exhaust Gas Recirculation, Level 1	Turbocharged Engine	100%	2010
HCR1	High Compression Ratio Engine, Level 1	HCR Engine	100%	2016
HCR2	High Compression Ratio Engine, Level 2	HCR Engine	100%	2016
VCR	Variable Compression Ratio Engine	VCR Engine	100%	2019
ADEAC	Advanced Cylinder Deactivation	Advanced DEAC Engine	100%	2019
ADSL	Advanced Diesel	Diesel Engine	100%	2010
DSLI	Diesel Engine Improvements	Diesel Engine	100%	2010

Table VI-27 – CAFE Model Engine Phase-in Caps for the Final Rule Analysis

NAME	TECHNOLOGY DESCRIPTION	TECHNOLOGY PATHWAY	PHASE-IN CAP	PHASE-IN START YEAR
EFR	Improved Engine Friction Reduction	Engine Improvements	20%	2017
VVT	Variable Valve Timing	Basic Engine	100%	2000
VVL	Variable Valve Lift	Basic Engine	100%	2000
SGDI	Stoichiometric Gasoline Direct Injection	Basic Engine	100%	2000
DEAC	Cylinder Deactivation	Basic Engine	100%	2004
TURBO1	Turbocharging and Downsizing, Level 1	Turbo Engine	100%	2004
TURBO2	Turbocharging and Downsizing, Level 2	Turbo Engine	100%	2010
CEGR1	Cooled Exhaust Gas Recirculation, Level 1	Turbo Engine	100%	2010
ADEAC	Advanced Cylinder Deactivation	Advanced DEAC Engine	64%	2019
HCR0	High Compression Ratio Engine, Level 1	HCR Engine	100%	2010
HCR1	High Compression Ratio Engine, Level 1 (Plus)	HCR Engine	100%	2017

HCR2	High Compression Ratio Engine, Level 2	HCR Engine	100%	2017
VCR	Variable Compression Ratio Engine	VCR Engine	20%	2019
VTG	Variable Turbo Geometry	VTG Engine	34%	2016
VTGE	Variable Turbo Geometry (Electric)	VTG Engine	20%	2016
TURBOD	Turbocharging and Downsizing with Cylinder Deactivation	Advanced Turbo Engine	20%	2016
TURBOAD	Turbocharging and Downsizing with Advanced Cylinder Deactivation	Advanced Turbo Engine	34%	2020
ADSL	Advanced Diesel	Diesel Engine	100%	2010
DSLI	Diesel Engine Improvements	Diesel Engine	100%	2010
DSLIAD	Diesel Engine Improvements with Advanced Cylinder Deactivation	Diesel Engine	34%	2023

Comments received on engine adoption features were mixed, with manufacturers generally supporting the NPRM methodology, and NGOs opposing it. Several manufacturers commented, both in their public comments or on a CBI basis, that many of the emerging engine technologies had the potential to improve vehicle fuel economy, but were technically complex and addressed many of the same issues as other existing engine technologies.

We agree with manufacturers that broadly, there are technologies that, in theory, present large potential effectiveness improvements like VCR, ADEAC, and others. However, the agencies believe it is important to assure realistic adoption of these technologies into the fleet in the rule making time frame, so that the rulemaking analysis accurately represents the costs and benefits of different regulatory alternatives considered. If the agencies were to select stringency based on an assumption that an emerging technology would see widespread adoption, and then it does not, the benefits of that stringency level would not be realized. The agencies have taken steps in NPRM and this final rule analysis to consider the manufacturability and feasibility of these technologies for different vehicle types and manufacturers. Discussed earlier, the analysis considers these and other concerns by accounting for product cadence, and by implementing phase-in caps and skips, and by designating technology phase-in and phase-out years. Similar to the 2012 final rule, this final rule analysis employed these strategies to reflect better the real-world considerations faced by manufacturers.

EDF commented, "EPA's task is thus to identify the major steps necessary for "development and application of the requisite technology," and then the respective standard "shall take effect." These individual decisions are highly consequential: as noted above, without changing anything else about the agencies' analysis, allowing HCR2 would reduce augural compliance costs by $619—or about 30% of the total difference between the augural and

rollback scenarios. The proposal's rejection of these technologies nowhere justifies how the (unfounded and cursorily justified) concerns accord with the agency's limited discretion under Section 202(a)(2) and duty to "press for the development and application of improved technology rather than be limited by that which exists today." If the agency is to predict more than the results of merely assembling pre-existing components, it must have some leeway to deduce results that are not represented by present data."[748]

CARB also commented that CAFE Model prevents manufacturers "from switching between a turbocharged and HCR pathways under the premise that manufacturers either would not develop both or would be committed irreversibly to one path or the other. This assumption is not based in reality and is not reflective of actual industry practice—manufacturers who have pursued turbocharging have also already pursued HCR engines for other vehicles in their line-up. For example, General Motors (GM) utilizes downsized turbocharging in some vehicles, such as the newly designed 2019MY Silverado pick-up and the Malibu sedan which has two different turbocharged engine options. GM also has a third offering in the Malibu sedan which is an HCR naturally aspirated 1.8L equipped with cooled exhaust gas recirculation (CEGR) mated to a hybrid electric system."[749]

The agencies do not agree with these comments about NPRM analysis constraints. The earlier engine modeling section, elaborated on the different types of HCR engines including how each of these types of engine can and cannot meet the performance and utility requirements for each vehicle type. The agencies incorporated HCR0 into the final rule analysis to improve the constraints, but still use the remaining constraints from NPRM analysis.

Commented [A245]: REVISE: If this is supposed to be responsive to CARB's comment, it's not: CARB is saying that the Malibu has both turbo and HCR engines, while this response suggests that's impossible.

The following sections discuss adoption features specific to individual engine technologies, including comments received and updates (or not) for the final rule analysis.

(1) Basic Engines

Most vehicles in the MY2017 analysis fleet that are DOHC or SOHC/OHV spark ignited engines and are not downsized turbocharged engines have any two combinations of VVT, VVL, SGDI or DEAC.[750]

For the NPRM, only engines with 6-cylinders or more could adopt DEAC and ADEAC.

HD Systems (HDS) on behalf of CARB commented that in the NPRM analysis VVL, which is cost ineffective compared to other conventional technologies, was always included in an adopted technology package.[751] HDS further stated that the "effectiveness of VVL is even smaller when the technology is combined with turbocharged downsized engines." Accordingly, HDS stated that removing VVL from the base pathway would save $314 but reduce fuel economy by only 1.4%.

[748] [EDF at p. x.]
[749] [CARB at p.x.]
[750] [The 2018 EPA Automotive Trends Report at p. 72.]
[751] [HD Systems comment at p.34.]

The agencies do not agree with HDS' assessment of the NPRM analysis that VVL was forced to be adopted in the fleet ~~and of how technology effectives values compare to LPM estimates~~. Discussed earlier in the effectiveness and modeling section, we model and simulate each engine technology independently and allow the CAFE model to adopt the most cost effectiveness technology. ~~So, it is inaccurate to state that a technology is less effective especially when comparing LPM.~~ In addition, VVL technologies reduce pumping losses in engines so it realistic that other technologies that also reduce pumping losses have synergetic effect. This specifically true for turbocharged engines.

Commented [A246]: DELETE: There is no reference to LPM in the quoted comment above. This should be removed.

ICCT commented that cylinder deactivation (DEAC) technology should be available for every engine, and should not be limited to 6-cylinder and higher cylinder count engines. ICCT and CARB also commented that DEAC should be allowed on turbocharged engines. ICCT also commented that advanced cylinder deactivation (ADEAC) should be widely available as it can be a viable technology application for various other powertrain technology combinations.[752] Furthermore, CARB commented "automakers will combine technologies like turbocharging, HCR and DEAC as well as more technologies when they have cost-effectiveness synergies."[753]

The agencies agree with ICCT that DEAC and ADEAC could be applied to additional engine types, including turbocharged engines. However, we disagree with ICCT that ADEAC should be widely applied to all powertrain technology combinations in this analysis. The agencies have updated the final rule analysis to allow DEAC and ADEAC for various engine cylinder counts and for turbocharged engines.

For the final rule analysis, both DEAC and ADEAC technologies can be adopted by any naturally aspirated engine. Similarly, any turbocharged engine can also adopt cylinder deactivation technology, as characterized by TURBOD and TURBOAD in the CAFE model. In this final rule analysis, the agencies distinguished cylinder deactivation technologies between naturally aspirated and forced air induction systems.

For the final rule analysis, the agencies allow any combination of VVT, VVL, SGDI and DEAC to be adopted for any engine displacement and cylinder count. Figure VI-10 below shows the basic engine paths a vehicle could traverse for the final rule analysis. Similar to the NPRM, the agencies have not changed the adoption features of these technologies shown in Figure VI-10 with exception of one. Vehicles that are SOHC or DOHC configuration that do not have VVT in the baseline can now adopt it.

Finally, the agencies disagree with ICCT and CARB that these DEAC, ADEAC, TURBOD, and TURBOAD should apply beyond these configurations. DEAC's fundamental benefits are driven by reducing pumping losses and by enabling the engine to operate in a more thermal efficient region of the engine fuel map. Conventional spark-ignited engines control airflow into the cylinders via a throttle operated by the driver to provide the level of power that is delivered.[754] In an 8-cylinder engine, when driving in light load conditions such as highway

[752] International Council on Clean Transportation, Attachment 3, Docket No. NHTSA-2018-0067-11741, at I-13.
[753] CARB at p. x.
[754] A throttle is the mechanism by which fluid flow is managed by constriction or obstruction. An engine's power can be increased or decreased by the restriction of inlet gases, but usually decreased.

driving, there are lower engine power requirements. In a throttle controlled system, engine pumping losses increase as air flow decreases. A way to reduce pumping loss in an engine is by increasing the airflow into the cylinders. By deactivating a set of cylinders, the same power output can be delivered by a "smaller" engine. Many technologies modeled for this analysis attempt to achieve the same concept of reduce pumping losses but through other mechanisms like VVT, VVL, downsized engines with turbochargers, high compression Atkinson mode cycle, and Miller Cycle.[755] Transmissions with a higher number of gears also provide the opportunity to reduce pumping work of the engine.[756]

As discussed earlier, DEAC can reduce pumping losses, so when combined with other technologies that also reduce pumping losses, like downsized turbocharged engines, the benefits for cylinder deactivation are lower than for naturally aspirated engines because downsized turbocharged engines already have lower pumping losses due to having a downsized engine.[757]

(2) Turbocharged Downsized Engines

About 23% of the MY2017 baseline fleet had adopted turbocharged engines. For this final rule analysis, the agencies allow any basic engine to adopt turbocharged engines (TURBO1, TURBO2 and CEGR1) from the Turbo path similar to the NPRM analysis. This includes any combination of VVT, VVL, SGDI and DEAC for both SOHC and DOHC configurations. Vehicles that have turbocharged engines in the baseline fleet will stay on the turbo engine path to prevent unrealistic engine technology change in a short timeframe considered in the rulemaking analysis. Turbo path is a mutually exclusive technology in that it cannot be adopted for HCR, diesel, ADEAC, CNG and powersplit PHEVs.

(3) Non-HEV Atkinson Mode Engines

[Text forthcoming]

(4) Advanced Cylinder Deactivation Technology

In the NPRM, any basic engine technology could adopt ADEAC. Commenters stated that the agencies restricted ADEAC technologies in the NPRM analysis to naturally aspirated engines.

ICCT provided a broad comment regarding the treatment of advanced technologies, including ADEAC, and criticized how the NPRM "removed many technologies that are viable and being actively deployed by the auto industry." ICCT specifically criticized "cases where viable technology combinations are disallowed" such as "turbocharging and cylinder deactivation (DEAC)."[758]

[755] 2015 NAS at p. 23.
[756] 2015 NAS at p.173.
[757] 2015 NAS at p. 34.
[758] ICCT Comments

UCS also commented on how the ADEAC technology was applied in the NPRM, stating "While the agencies have acknowledged the existence of dynamic cylinder deactivation, they have not appropriately included it as an available technology, dramatically limiting its availability." UCS specifically disagreed with adoption features of the ADEC, noting the technology "is restricted to naturally aspirated, low-compression ratio engines—it cannot be combined with turbocharged engines, high compression ratio engines, or variable compression ratio engines due to pathway exclusivity in the Volpe model."[759] CARB and Meszler mirrored these concerns.[760]

The agencies agreed with commenters and in response have allowed both naturally aspirated engines and turbocharged engines to adopt ADEAC in the final rule analysis. The new Advanced Turbocharging path includes TURBOD and TURBOAD, while naturally aspirated engines use the same ADEAC engine designation. There is some potential for this type of technology to improve fuel economy and reduce CO_2 emissions, however, the technology provides diminishing returns if it is included with engine downsizing or other technologies that already reduce pumping losses. Accordingly, once a vehicle has adopted ADEAC, TURBOD, or TURBOAD, we did not allow further adoption of other engine technologies that reduce pumping losses such as VCR and VTG.

(5) Miller Cycle Engines

Miller cycle engines technologies (VTG and VTGe) are new for this final rule analysis, and VTG engines could be applied to any basic and turbocharged engine. Discussed earlier, the VTGe technology is enabled by the use of a 48V system that presents an improvement from traditional turbocharged engines, and accordingly VTGe could only be applied with a mild hybrid system.

(6) Variable Compression Ratio Engines

In the NPRM analysis, VCR technology was not available for adoption, but the engine map and specifications were provided for review. For this final rule analysis, VCR engines are included in the analysis and can be applied to basic and turbocharged engines, however the technology is limited to Nissan. VCR technology requires a complete redesign of the engine, and in MY2020, only two of Nissan's models had incorporated this technology. In addition, the technology showed lower fuel savings than expected.[761, 762] The agencies do not believe any other manufacturers will invest to develop and market this technology in their fleet in the rulemaking time frame.

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[759] UCS Comments

[760] Comments from CARB , Comments from Meszler

[761] [Nissan Altima and Infinity QX50 – based on PMY data.]

[762] VanderWerp, D. "Why Nissan's Holy-Grail VC-T Engine Doesn't Achieve Better Fuel Economy," C/D Nov 1, 2018. Available at https://www.caranddriver.com/features/a24434937/nissan-new-vc-t-engine-fuel-economy/. Last accessed Dec. 19, 2019.

(7) Diesel Engines

Diesel engine adoption and features have been carried from the NPRM analysis for this final rule analysis for ADSL and DSLI. Any basic engine technologies (VVT, VVL, SGDI, and DEAC) can adopt ADSL and DSLI engine technologies. New for the final rule analysis is the adoption of advanced cylinder deactivation for diesel engines (DSLIAD). Any basic engine and diesel engine can adopt this technology in the final rule analysis; however, the agencies have applied a phase in cap and year for this technology at 34% and MY2023, respectively. In our engineering judgement, the agencies have concluded that this is rather complex and costly technology to adopt and think that it could take significant investment to develop. For more than a decade, diesel engine technologies have been used in less than one percent of the total light-duty fleet production and the investment for this cylinder deactivation technologies may not be justifiable.[763]

(8) Alternative Fuel Engines

Adoption features for alternative fueled engines (CNG) have been carried over from the NPRM for this final rule analysis. Because CNG is considered an alternative fuel under EPCA/EISA, it cannot be adopted during the rulemaking timeframe for NHTSA's standard setting analysis. The EPA analysis was modeled separately in the CAFE model without such constraints.

(9) Engine Lubrication and Friction Reduction

Finally, new for this analysis is the addition of EFR. We allow EFR to apply to any engine technology except for DSLI and DSLIAD. DSLI and DSLIAD inherently have incorporated engine friction technologies from ADSL. In addition, friction reduction technologies that apply to gasoline engines cannot necessarily be applied to diesel engines due to the higher temperature and pressure operation in diesel engines.

(10) Engine Effectiveness Modeling and Effectiveness Values

Figure VI-12 below shows the effectivness estimates from all the vehicle types for the NPRM analysis using Autonomie full vehicle modeling and simulation.

[763] [The 2018 EPA Automotive Trends Report Table 4.1 at p. 72.]

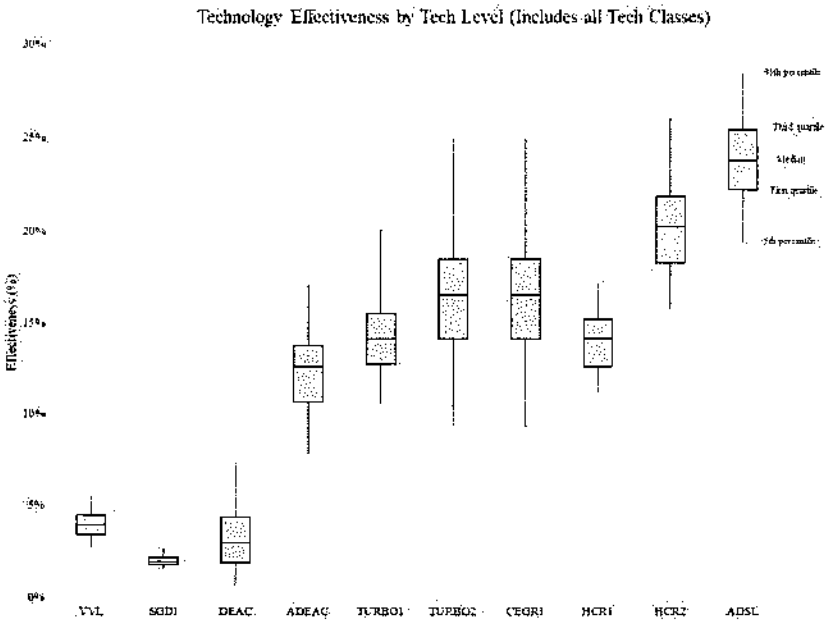

Figure VI-12 – NPRM Technology Effectiveness by Engine Technologies Relative Base

Roush commented that they had observed wide variations in estimated incremental effectiveness associated with individual technology packages between the 2016 Draft TAR and NPRM analysis. "Furthermore, even the bases for evaluation can vary significantly and inappropriate product improvement pathways result."[764]

The agencies agree that to predict potential incremental improvements in fuel efficiency accurately, it is extremely important to understand the nature of the improvements being sought by each increment (improved thermodynamics, reduced friction, reduced vehicle weight, etc.). The technology modeling and large scale simulation used for the proposal and updated for the final rule does exactly that. In fact, the NPRM and final rule use these methods more expansively than any previous CAFE and CO_2 rulemaking, including the 2016 Draft TAR and 2016 EPA Proposed Determination.

[764] [Roush at p. x. The results of our initial assessment suggest that there are seemingly wide variations in estimated incremental benefits associated with individual technology packages between the 2016 Draft TAR and 2018 PRIA. Furthermore, even the bases for evaluation can vary significantly and inappropriate product improvement pathways result.]

One commenter stated the effectiveness for ADEAC was overestimated for the NPRM, and that data from compliance shows much lower effectiveness.[765] The agencies disagree with this comment, it is invalid to compare effectiveness of full vehicle compliance data directly to the incremental effect modeled for ADEAC. For reasons discussed earlier [see paragraph X], data from full vehicle benchmarking cannot be used as a comparison for specific technology effectiveness. The effectiveness estimated for this technology is in line with test data, CBI and engineering analysis.[766]

Engine effectiveness estimates remained the same for most technologies from the NPRM analysis, with the exception of some technologies that had characteristics updated, and the new added engine technologies. For the final rule analysis, the agencies used the same effectiveness values for ADEAC applied to naturally aspirated engines as in the NPRM, and incorporated estimated effectiveness values for TURBOAD to represent ADEAC on downsized turbocharged engines.

Other technology-specific comments and the agencies' responses are provided within the discussion of each technology throughout this section, as those comments tended to be predicated on issues surrounding the engine maps used to model technologies or technology-specific adoption features. For the final rule analysis, the technical merits of the substantive comments and any accompanying publications and information were carefully considered and discussed in the subsections where appropriate.

Figure VI-13 below shows the effectivness estimates from all the vehicle types for the FRM analysis using Autonomie full vehicle modeling.

[765] [text forthcoming]
[766] [References for ADEAD effectiveness.]

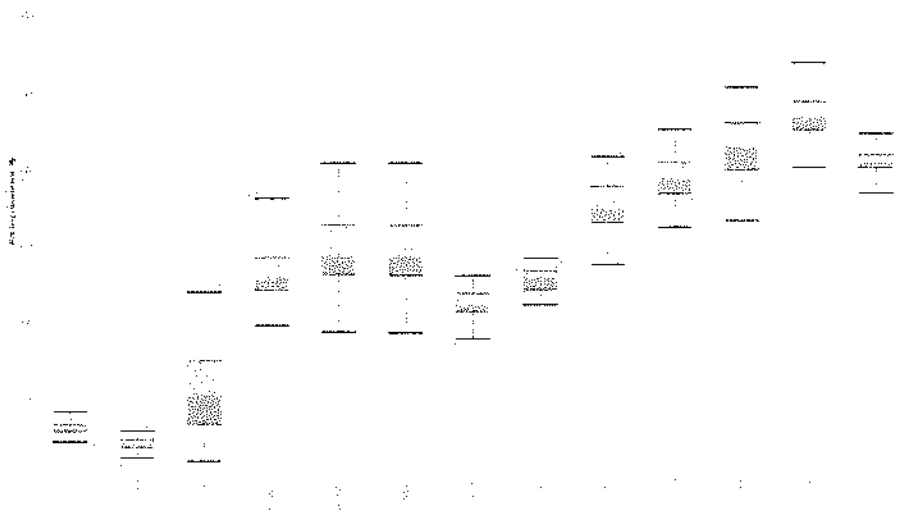

Figure VI-13 – FRM Technology Effectiveness Estimates by Engine Technologies Relative to Base

f) Engine Costs

Discussed in the NPRM PRIA, the agencies spent millions of dollars sponsoring research to determine direct manufacturing costs (DMCs) for fuel saving technologies since the 2012 rule.[767] Because a major objective of the studies was to consider costs in the rulemaking timeframe, the agencies believed that these costs were appropriate to use for the NPRM and final rule analysis.

[table forthcoming]

CARB commented that costs associated with IC engines were not excluded from the final costs of BEV vehicles.[768] Inherently, the final costs of BEV vehicles are higher due to the inclusion of the base absolute costs, to which the assigned BEV incremental cost would be added.

[767] FEV prepared several cost analysis studies for EPA on subjects ranging from advanced 8-speed transmissions to belt alternator starter, or Start/Stop systems. NHTSA also contracted with Electricore, EDAG, and Southwest Research on teardown studies evaluating mass reduction and transmissions. The 2015 NAS report on fuel economy technologies for light-duty vehicles also evaluated the agencies' technology costs developed based on these teardown studies, and the technology costs used in this proposal were updated accordingly. These studies are discussed in detail in Chapter 6 of the RIA accompanying the NPRM proposal.
[768] [CARB comments about total BEV cost.]

The agencies agree with CARB that inclusion of IC engine costs in the BEV was an error in the analysis. In response to this comment, the agencies have developed absolute costs for baseline engines for displacement of powertrain systems. In the CAFE final rule analysis, once a vehicle adopts BEV technology, we remove costs associated with powertrain systems. Due to the extensive variations in engine technologies in real world production, the agencies relied on discrete publication costs and historical studies to assign costs for base engines.[769, 770] For this final rule analysis, the agencies have included these costs for base engines shown in Table VI-28. Discussion of how these costs were developed for the final rule analysis can be found in the FRIA.

Table VI-28 – Examples of Absolute Costs for Engines in 2018 Dollars

	I4	V6	V8
SOHC	5,013.49	5,675.87	6,306.65
DOHC	5,090.94	5,830.76	6,461.54

[Text forth coming]

HDS provided a variety of costs and effectiveness comparisons between the NPRM and previous 2012 final rule and the 2016 Draft TAR.[771] Specifically, H-D systems stated that the data presented in the 2016 TAR indicated a $60 per CO_2/mile reduction for most conventional engine technologies.

Although the comparison was technically sound, there are significant differences between the Draft TAR and NPRM analyses that clearly account for the differences in engine cost. First, the NPRM analysis used the MY2016 fleet as a starting point to model manufacturers' potential responses to CAFE and CO_2 standards, whereas the 2012 final rule and Draft TAR used older baseline fleets. For example, EPA used MY 2014 baseline fleet for the draft TAR analysis. Vehicles in the MY 2016 fleet already included more advanced technologies than their predecessors in prior MY fleets, which would make it more expensive for vehicles that have already adopted advanced technologies to adopt more advanced technology. Second, the agencies refined the engine modeling from previous analysis to the NPRM to account for engine configurations and cylinder count more precisely. For the final rule analysis, the same approach was taken to account appropriately for costs for different type engine designs and configurations.

Commented [A247]: **REVISE:** Not clear what this means. Why does the existence of Technology X affect the cost of Technology Y?

Aside from these updates, engine costs were carried over from the NPRM analysis, except for newly added technologies, where costs were obtained from various sources such as

[769] [FEV cost study.]
[770] [Chevy Bolt teardown study.]
[771] [HD systems costs comments.]

NAS studies, technical publications, and CBI data. Finally, the cost estimates have been updated to account for dollar year (updated from 2106 dollars to 2018 dollars), and learning rate.

(1) Basic Engines

DMCs used for the final rule analysis for basic engine technologies were the same as NPRM costs.

[Text Forthcoming]

Table VI-29 – Examples of Costs for Basic I4 Engines Used for the FRM Analysis in 2018 Dollars (costs includes DMCs, RPE and learning rate factor)

	COST			
Name	**2018**	**2021**	**2026**	**2029**
VVT	115.83	113.43	110.18	108.57
VVL	316.16	309.61	300.73	296.33
SGDI	349.73	342.48	332.66	327.79
DEAC	180.20	176.47	171.41	168.90

Table VI-30 – Examples of Costs for Basic V6 Engines Used for the FRM Analysis in 2018 Dollars

	COST			
Name	**2018**	**2021**	**2025**	**2029**
VVT	231.67	226.86	221.54	217.14
VVL	474.25	464.41	453.52	444.50
SGDI	524.60	513.72	501.67	491.69
DEAC	212.64	208.23	203.35	199.30

(2) Turbocharged Downsized Engines

DMCs used for the final rule analysis for the turbocharged engine technologies were the same as NPRM costs. When these technologies are applied to V6 and V8 non-turbocharged engines, the incremental I4 and V6 turbocharged costs are applied, respectively.

[table forthcoming]

Table VI-31 – Examples of Costs Used for FRM Analysis for I4 Turbocharged Engines in 2018 Dollars (costs include DMCs, RPE and learning rate factor)

	COST			
Name	**2018**	**2021**	**2026**	**2029**
TURBO1	6,264.69	6,215.86	6,173.75	6,156.88
TURBO2	6,861.47	6,772.50	6,616.76	6,554.61
CEGR1	7,288.46	7,178.04	6,984.74	6,907.60

Table VI-32 – Examples of Costs used for FRM Analysis for V6 Turbocharged Engines (costs include DMC, RPE and learning rate factor)

	COST			
Name	**2018**	**2021**	**2025**	**2029**
TURBO1	7,112.60	7,059.27	7,020.02	6,994.87
TURBO2	7,731.51	7,636.00	7,498.58	7,402.08
CEGR1	8,158.51	8,041.54	7,873.26	7,755.08

(3) Non-HEV Atkinson and Atkinson Engines

DMCs used for the final rule analysis used for HCR0 and HCR1 were based on HCR1 and HCR2 from NPRM, respectively. Discussed in the engines section, the agencies aligned the cost of HCR technologies to align with 2015 NAS effectiveness and costs.

Several commenters commented on the costs of HCR technology compared to previous analysis. ICCT compared the NPRM costs to EPA's Proposed Determination costs, stating that "[t]his is a clear case where the agencies appear to have not used the best available data from EPA which has extensively analyzed this technology and its associated cost, nor have the agencies justified how they have increased the associated costs, apparently by a factor of three." Similarly, Roush Industries commenting on behalf of CARB stated that the costs for implementing HCR technology were 5-6 times the 2016 Draft TAR estimated costs, which are "extremely high" and "will significantly overstate the incremental cost and bias technology pathways."[772] HDS also commented that the costs for HCR technology were higher than the costs from the 2016 Draft TAR, and speculated that was due to "the bulky exhaust system used in the Mazda ATK1 engine, which apart from being expensive also requires the vehicle to be

[772] NHTSA-2018-0067-11984.

modified to accommodate the exhaust system."[773] HDS cited the 2018 Camry as an example of a vehicle that does not use the same exhaust system, but stated the sources of the new cost data were not documented in the PRIA.

ICCT stated that "[t]he agencies should reinstate the better justified and more deeply analyzed original Proposed Determination HCR cost numbers from EPA for this rulemaking."

The NPRM analysis and this final rule, have used the same DMC costs that were established by the 2015 NAS report for the Atkinsons cycle technologies. However, because there are many variations engine configurations the market we don't use the same fixed costs that were set for each type of vehicle described in the 2015 NAS such as pickup and sedan. We have expanded our costs to take into account the type technology that's in the baseline and what is the configuration of the engine such as SOHC versus DOHC. In addition, the cost used in the NPRM also included updated dollar year, learning rate, and RPE. And so, for the final rule analysis the agencies will continue to use the same DMC for HCR technologies.

Commented [A248]: REVISE: This paragraph is not really responsive to the comment, other than to say we're not doing what was suggested.

[Text Forthcoming]

Table VI-33 – Examples of Costs for Final Rule Analysis for I4 HCR Engines (costs include DMC, RPE and learning rate factor) in 2018 Dollars

	COST			
Name	**2018**	**2021**	**2026**	**2029**
HCR0	5,843.55	5,812.69	5,803.22	5,801.68
HCR1	5,898.80	5,851.67	5,831.19	5,826.67
HCR2	6,113.55	6,113.55	6,113.55	6,113.55

Table VI-34 – Examples of Costs for Final Rule Analysis for V6 HCR Engines (costs include DMC, RPE and learning rate factor) in 2018 Dollars

	COST			
Name	**2018**	**2021**	**2025**	**2029**
HCR0	6,990.13	6,942.58	6,928.79	6,925.64
HCR1	7,045.38	6,981.56	6,958.18	6,950.62
HCR2	7,384.64	7,384.64	7,384.64	7,384.64

[773] NHTSA-2018-0067-11985.

(4) Advanced Cylinder Deactivation Technologies

DMCs used for the final rule analysis for the advanced cylinder deactivations technologies were the same as NPRM costs.

Roush commented that in the NPRM analysis, the agencies did not properly consider the "very cost-effective benefits of skip-fire technology," referred to in the analysis as ADEAC. Roush stated that "due to extremely high estimated cost ($1,250.00 in MY2016), the benefits of this technology will likely not be chosen in any reasonable technology pathway. If included, the predicted cost for that pathway will be overestimated by $750.00 - $1,000.00."[774]

Similarly, Meszler commented on the cost for the ADEAC system stating "advanced cylinder deactivation paths are assumed (by NHTSA) to be expensive, and are selected only in rare instances."[775]

ICCT also stated "The agencies estimated a greatly exaggerated cost of advanced cylinder deactivation for that level of the technology." [776]

The agencies do not agree with the commenter's statement that the analysis did not consider ADEAC as cost effective technology or that the agencies overestimated costs for the technology. The agencies considered the most up to date information and data for the NPRM and final rule analysis.[777] The agencies rely on the CAFE model to determine technology cost effectiveness, and if the technology was cost effective for a manufacturer to adopt, then the model would apply it to a manufacturer's vehicle. The adoption of ADEAC was applied to vehicles with corresponding technology combinations to reflect appropriate cost and effectiveness, as discussed in the paragraph above. The purpose of ADEAC is to reduce pumping losses, but if the engine has been downsized, or has already incorporated technologies that also reduce pumping loss, then it is likely the ADEAC has reached a point of diminishing return. As far as the agencies are aware, Roush did not provide alternative DMCs for ADEAC technology.

Commented [A249]: **REVISE:** This seems non-responsive to the comment. Commenters are saying the absolute costs are too high (leading to poor cost effectiveness), and are *not* saying that somehow the cost-effectiveness was ignored.

[Text Forthcoming]

Table VI-35 – Examples of I4 Costs for ADEAC Used for the Final Rule (costs include DMC, RPE and learning rate factor)

	COST			
Name	**2018**	**2021**	**2026**	**2029**
ADEAC	6,334.53	6,273.03	6,207.62	6,181.95

[774] Roush at p.x.
[775] Meszler Comments, Attachment 2, NHTSA Docket No. NHTSA-2018-0067-11723
[776] ICCT comments, NHTSA-2018-0067-11741, Page I-71
[777] [Text Forthcoming]

Table VI-36 – Examples of I4 Costs for TURBOD and TURBOAD Used for the Final Rule (costs include DMC, RPE and learning rate factor)

	COST			
Name	**2018**	**2021**	**2026**	**2029**
TURBOD	6,444.89	6,392.32	6,345.15	6,325.78
TURBOAD	7,042.71	6,942.03	6,847.59	6,811.54

Table VI-37 – Examples of V6 Costs for ADEAC Used for the Final Rule (costs include DMC, RPE and learning rate factor)

	COST			
Name	**2018**	**2021**	**2025**	**2029**
ADEAC	7,696.40	7,604.14	7,521.16	7,467.52

Table VI-38 – Examples of V6 costs for TURBOD and TURBOAD Used for the Final Rule (costs include DMC, RPE and learning rate factor)

	COST			
Name	**2018**	**2021**	**2025**	**2029**
TURBOD	7,292.80	7,235.74	7,192.35	7,163.77
TURBOAD	7,890.63	7,785.45	7,701.57	7,649.52

(5) Miller Cycle Engines

The agencies estimated costs for Miller Cycle Engines with VGT from 2016 ICCT sponsored FEV technology cost assessment report. The agencies considered costs from 2015 NAS study that referenced NESCCAFF 2004 report, but believed that the reference material from the ICCT report had more updated cost estimates for this technology that represented what was discussed in the NPRM and modeled in the FRM analysis.[778, 779]

NAS estimated incremental cost for VGT was $525 plus multiplying learning factor of 0.76 other costs in 2010$ in 2015 NAS study, but this cost assumes many of the traditional turbocharged components and adds VVT, VVL and SGDI. In addition, VTG (Eng23b) and

[778] "Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles." NESCCAF. September 23, 2004 Report. Available at https://www.nesccaf.org/documents/rpt040923ghglightduty.pdf/. Last accessed Dec. 22, 2019.
[779] "VGT gasoline turbo, charge air cooler, piston upgrade, piston cooling, steel crankshaft, cooling system upsize, plumbing, rings, pressure sensor & bearing upgrade. Excludes any needed increase in transmission torque capacity or modifications to aftertreatment system." NESCCAF Report comment (2004).

VTGe (Eng23c) engines both have similar modeled BMEP level and cool EGR system as CEGR1 (Eng14), implying that the components such as cooling systems and piping will have similar costs.

The NAS template to calculating the final DMCs for the Miller Cycle Engines for the different engine configuration is the $525 (2010$) plus cost of cEGR1 minus cost of VVT, VVL, and SGDI. The agencies estimated cost for electrically assisted variable supercharger VTGe (Eng23c) engines are based on the 2015 NAS study that uses cost of $1050 (2010$) plus the cost of the mild hybrid battery cost. For the final rule analysis, the total costs for these technologies are shown below.

[Text Forthcoming]

Table VI-39 – Miller Cycle I4 Engines' Total Costs Used for the Final Rule Analysis (costs include DMC, RPE and learning rate factor)

	COST			
Name	2018	2021	2026	2029
VTG	7,663.31	7,547.20	7,343.96	7,262.86
VTGE	9,148.86	8,772.73	8,326.43	8,146.77

Table VI-40 – Miller Cycle V6 Engines' Total Costs Used for the Final Rule Analysis (costs include DMC, RPE and learning rate factor)

	COST			
Name	2018	2021	2025	2029
VTG	8,532.58	8,410.25	8,234.25	8,110.65
VTGE	10,018.13	9,635.78	9,257.62	8,994.56

(6) Variable Compression Ratio Engines

DMCs used for the final rule analysis for the VCR engines were based on the 2015 NAS report.[780] The 2015 NAS reported cost for VCR in MY2025 had a naturally aspirated engine; however, for this final rule analysis we have added cEGR and other engine technologies to the engine. Total costs were updated to reflect 2018 dollars and MY2017 learning rate which is based on the NPRM ADEAC learning rate.

[Text Forthcoming]

[780] 2015 NAS at p. 93.

Table VI-41 – Examples of VCR Engine Costs for I4 Engine Configuration (costs include DMC, RPE and learning rate factor)

	COST			
Name	2018	2021	2026	2029
VCR	7,472.47	7,326.44	7,188.83	7,138.25

Table VI-42 – Examples of VCR Engine Costs for V6 Engine Configuration (costs include DMC, RPE and learning rate factor)

	COST			
Name	2018	2021	2025	2029
VCR	8,320.38	8,169.86	8,048.82	7,976.24

(7) Diesel Engines

DMCs used for the final rule analysis for diesel engine technologies were the same as NPRM analysis. For DSLIAD technologies, the agencies have added the incremental cost of ADEAC to DSLI.

[Text Forthcoming]

Table VI-43 – Examples of Diesel Engine Costs for I4 Engine Configuration (costs include DMC, RPE and learning rate factor)

	COST			
Name	2018	2021	2026	2029
ADSL	9,832.87	9,619.75	9,438.06	9,373.18
DSLI	10,344.73	10,108.61	9,907.31	9,835.43
DSLIAD	10,942.56	10,658.32	10,409.75	10,321.18

Table VI-44 – Examples of Diesel Engine Costs for V6 Engine Configuration (costs include DMC, RPE and learning rate factor)

	COST			
Name	2018	2021	2025	2029
ADSL	11,512.42	11,257.06	11,065.55	10,961.64

DSLI	12,179.07	11,893.75	11,679.77	11,563.66
DSLIAD	13,075.80	12,718.32	12,443.61	12,292.29

(8) Alternative Fuel Engines

DMCs used for the final rule analysis for CNG engine technologies were the same as NPRM analysis.

[Text Forthcoming]

Table VI-45 – Examples of CNG Engine Costs for I4 Engine Configuration (costs include DMC, RPE and learning rate factor)

	COST			
Name	2018	2021	2026	2029
CNG	11,893.10	11,752.83	11,611.72	11,541.17

Table VI-46 – Examples of CNG Engine Costs for V6 Engine Configuration (costs include DMC, RPE and learning rate factor)

	COST			
Name	2018	2021	2025	2029
CNG	12,748.76	12,606.09	12,462.91	12,389.57

(9) Engine Lubrication and Friction Reduction Technologies

EFR costs used for the FRM analysis are based on the 2015 NAS assessment for Low Friction Lubrication and Engine Friction Reduction Level 2 (LUB2_EFR2). 2015 NAS estimates costs in 2015 dollars of $51 for midsize car I4 DOHC, and $72 [for V6 SOHC and DOHC] relative to Level 1 Engine Friction Reduction (EFR1) which costs about $12 per cylinder. For this analysis, EFR technologies DMCs are estimated to cost $14.05 per cylinder in 2016 dollars. The estimated effectiveness of 1.4% is applied to this technology. Total costs were updated to reflect 2018 dollars and MY 2017 learning rate.

[Text Forthcoming]

Table VI-47 – Example of EFR Costs Used for the I4 Engine Final Rule Analysis in 2018 Dollars (cost includes DMC, RPE and learning rate factor)

	COST

Name	2018	2021	2025	2029
EFR	66.61	66.61	63.97	59.01

Table VI-48 – Example of EFR Costs Used for V6 Engine the Final Rule Analysis in 2018 Dollars (cost includes DMC, RPE and learning rate factor)

	COST			
Name	2018	2021	2025	2029
EFR	99.92	99.92	95.96	88.51

2. Transmission Paths

Transmissions transmit torque from the engine to the wheels. Transmissions primarily use two mechanisms to improve fuel efficiency: (1) a higher gear count, as more gears allow the engine to operate longer at higher efficiency speed-load points; and (2) improvements in friction or shifting efficiency (e.g., improved gears, bearings, seals, and other components), which reduce parasitic losses.

There are two major categories of transmission types modeled in the analysis: automatic and manual. Automatic transmissions automatically select and shift between transmission gears for the driver during vehicle operation. The automatic transmission category is further subdivided into four subcategories: traditional automatic transmissions, dual clutch transmissions, continuously variable transmissions, and direct drive transmissions. Manual transmissions require direct control by the driver to select and shift between gears during vehicle operation.

Conventional planetary gear automatic transmissions (AT) are the most popular transmission.[781] ATs typically contain three or four planetary gear sets, providing the various gear ratios. Gear ratios are selected by activating solenoids which engage or release multiple clutches and brakes as needed. ATs with gear counts ranging from five speeds to ten speeds were considered in the NPRM and final rule analysis.[782]

ATs are packaged with torque converters, which provide a fluid coupling between the engine and the driveline, and provide a significant increase in launch torque. When transmitting torque through this fluid coupling, energy is lost due to the churning fluid. These losses can be

[781] "The 2018 EPA Automotive Trends Report," https://www.epa.gov/fuel-economy-trends/download-report-co2-and-fuel-economy-trends, Accessed Aug 23, 2019.
[782] Specifically, the agencies considered five-speed automatic transmissions (AT5), six-speed automatic transmissions (AT6), seven-speed automatic transmission (AT7), eight-speed automatic transmissions (AT8), nine-speed automatic transmissions (AT9), and ten-speed automatic transmissions (AT10).

eliminated by engaging the torque convertor clutch to directly connect the engine and transmission ("lockup").

Conventional continuously variable transmissions (CVT) consist of two cone-shaped pulleys, connected with a belt or chain. Moving the pulley halves allows the belt to ride inward or outward radially on each pulley, effectively changing the speed ratio between the pulleys. This ratio change is smooth and continuous, unlike the step changes of other transmission varieties. CVTs were not initially chosen in the fleet modeling for the 2012 rulemaking analysis for MYs 2017 and later because of the predicted low effectiveness associated with CVTs (due to the high internal losses and narrow ratio spans of CVTs in the fleet at that time).[783] However, improvements in CVTs in the current fleet have increased their effectiveness, leading to increased adoption rates in the fleet. In its 2015 report, the NAS recommended CVTs be added to the list of considered technologies. The agencies included CVT technology for the NPRM and this final rule analyses.

Dual clutch transmissions (DCT), like automatic transmissions, automate shift and launch functions. DCTs use separate clutches for even-numbered and odd-numbered gears, allowing the next gear needed to be pre-selected, resulting in faster shifting. The use of multiple clutches in place of a torque converter result in lower parasitic losses than ATs. However, DCTs are seeing limited penetration in the fleet, and because of the low penetration rate, only two DCTs were considered in the analysis.

Direct drive (DD) transmissions are a direct connection between the wheels and a drive motor. In a DD transmission, the ratio between wheel speed and motor speed remains constant. A DD transmission is only used in battery electric vehicles, and in the NPRM the agencies provided the specification for comments.[784]

Manual transmissions (MT) are transmissions that require direct control by the driver to operate the clutch and shift between gears. Manual transmissions have seen a significant reduction in application by automakers over recent years. As a result of the reduced market presence, only three variants are used in the analysis.

a) Transmission Modeling in the CAFE Model

The NPRM analysis modeled pathways for applying improved technology for each of the transmission categories and subcategories, except for the direct drive, which was only available in the battery electric vehicles. The MT and DCT pathways only included increasing gear counts (e.g. 5-speed manual transmission, 6-speed manual transmission, and 7-speed manual transmission) as improved technologies.

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[783] Morihiro, S.., "*Fuel Economy Improvement by Transmission*," presented at the CTI Symposium 8th International 2014 Automotive Transmissions, HEV and EV Drives.

[784] NHTSA-2018-0067-0003. ANL Autonomie Summary of Main Component Assumptions. Aug 21, 2018. NHTSA-2018-0067-0007. Islam, E. S, Moawad, A., Kim, N, Rousseau, A. "*A Detailed Vehicle Simulation Process To Support CAFE Standards 04262018 – Report*" ANL Autonomie Documentation. Aug 21, 2018.Aug 21, 2018 NHTSA-2018-0067-0004. ANL Autonomie Data Dictionary. Aug 21, 2018.

The traditional ATs and CVTs included both increased gear counts and high efficiency gearbox (HEG) technology improvements as options. HEG improvements for transmissions represent incremental advancement in technology that improves efficiency, such as: reduced friction seals, bearings and clutches, super finishing of gearbox parts, and improved lubrication. All these advancements are aimed at reducing frictional and other parasitic loads in transmissions which improve efficiency. Three levels of HEG improvements are considered in this analysis, based on 2015 NAS recommendations and based on CBI data.[785] HEG efficiency improvements were applied to ATs and CVTs, as those transmissions inherently have higher friction and parasitic loads related to hydraulic control systems and greater component complexity, compared to MTs and DCTs.

In total, 18 unique transmission technology combinations were simulated, using explicit input values for gear ratios, gear efficiencies, gear spans, shift logic, and transmission architecture.[786] [787] Table VI-49Table VI-49 shows a list of the multi-gear transmissions used for the NPRM.[788]

Table VI-49 - Transmissions used in NPRM analysis

Transmission	NPRM Name
5-speed automatic	AT5 / 5AU
6-speed automatic baseline	AT6 / 6AU
6-speed automatic level 2 HEG	AT6L2 / 6AUp
7-speed automatic level 2 HEG	AT7 / 7AU
8-speed automatic baseline	AT8 / 8AU
8-speed automatic level 2 HEG	AT8L2 / 8AUp
8-speed automatic level 3 HEG	AT8L3 / 8AUpp
9-speed automatic level 2 HEG	AT9 / 9AU
10-speed automatic level 2 HEG	AT10 / 10AUp
10-speed automatic level 3 HEG	AT10L2 / 10Upp
6-speed dual-clutch	6DCT
8-speed dual-clutch	8DCT
Continuous variable transmission	CVT
Continuous variable transmission level 2HEG	CVTL2A/2B
5-speed manual transmission	MT5
6-speed manual transmission	MT6
7-speed manual transmission	MT7

The technologies that made up the four transmission/level paths defined by the modeling system for the NPRM analysis are shown in Figure VI-14. Each vehicle model in the baseline fleet is assigned an initial transmission type and level that most closely matches its configuration and characteristics. The baseline-level technologies (AT5, MT5 and CVT) appear in gray boxes and are only used to represent the initial configuration of a vehicle's transmission in the baseline

[785] 2015 NAS Report, at 191.
[786] See PRIA Chapter 6.3.
[787] Ehsan, I. S., Moawad, A., Kim, N., & Rousseau, A.., "A Detailed Vehicle Simulation Process To Support CAFE Standards." ANL/ESD-18/6. Energy Systems Division, Argonne National Laboratory. 2018.
[788] The NPRM and final rule also included a direct drive transmission (single ratio) for BEVs.

fleet. Because there are only a few manual transmissions with less than five forward gears in the baseline fleet, for simplicity, all manual transmissions with five forward gears or fewer were designated MT5 for the analysis. Similarly, all automatic transmissions with five forward gears or fewer have been assigned the AT5 technology. For the NPRM analysis, the agencies included a 7-speed automatic and a 9-speed automatic to account for effectiveness of those transmissions in the baseline fleet. These two transmissions were not available for adoption but were available as initial configurations, and appear in gray boxes in Figure VI-14.

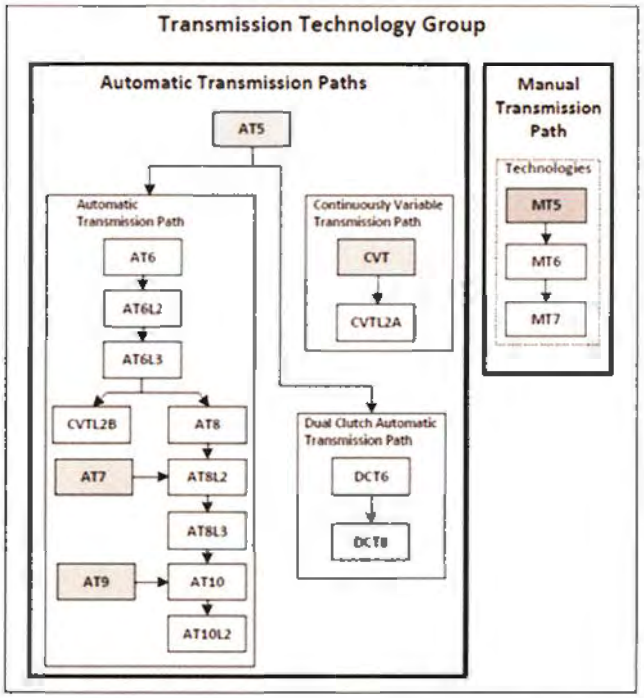

Figure VI-14 - NPRM Transmission Paths

The model generally may apply any of the more efficient transmission technologies that are contained within the pathway of the baseline vehicle initial transmission configuration. The model prohibits manual transmissions from becoming automatic transmissions. Automatic transmissions may become CVT level 2 after progressing though the 6-speed automatic, as shown in Figure VI-14**Error! Reference source not found.**. While the structure of the model could allow automatic transmissions to consider applying a DCT, the market data file was used to preclude the application of DCTs to automatic transmission vehicles, as discussed further in Transmission Adoption Features Section, below.

The model does not attempt to simulate "reversion" to less advanced transmission technologies, such as replacing a 6-speed AT with a DCT and then replacing that DCT with a 10-speed AT. The agencies invited comment on whether the model should be modified to simulate "reversion" and, if so, how this possible behavior might be practicably simulated. Richard Rykowski, supporting comments from the Environmental Defense Fund (EDF), broadly discussed the concept of reversion in the CAFE model, and included an example relating to the transmission technology paths.[789] Mr. Rykowski stated that it is "possible that the model could add a 10-speed transmission to a vehicle with a very basic engine" and then as the simulation progressed and "the manufacturer required greater fuel or CO_2 emission control, the Volpe Model might move to a TURBO1 or HCR engine" and the vehicle would no longer need the 10-speed transmission to meet standards, and a 6-speed or 8-speed transmission might be more cost effective.

The scenario discussed by Mr. Rykowski is very unlikely. The CAFE model cost optimization algorithm considers both current and future standard requirements when selecting current MY technologies. The algorithm will look multiple years into the future and compare multiple potential technology paths going forward for the most cost-effective path. For a more detailed discussion on the cost optimization algorithm please see [CAFE model section].

Regarding the types of transmission technologies modeled, Meszler Engineering Services provided a comment criticizing the limited number of manual transmission model options and the limited technology paths available to vehicles with manual transmissions. The agencies do not agree with Meszler Engineering Service's assessment. The manual transmission path includes three model options and allows for the vehicles to receive electrification in the form of SS12V and BISG technologies. The agencies believe the technology paths dedicated to manual transmission was appropriate for vehicles that typically represent manufacturers' specialty performance cars, such as the Subaru STI or BMW M-series, and an overall fleet share of less than 2 percent.

Commenters also discussed potential missing transmission technologies in the NPRM analysis. ICCT stated that the agencies failed to consider transmission warm-up technologies, which are available in 3.7 million new vehicles in the MY 2016 fleet, that are being deployed due to regulatory test-cycle benefits and off-cycle credits.[790] In addition, the Fiat Chrysler Automobiles (FCA) also expressed concern over the lack of inclusion of thermal bypass devices in the modeling of transmission technologies.[791]

We agree with parts of ICCT's and the FCAs comments and disagree with other parts. We do agree with ICCT and the Auto Alliance that the analysis should consider the off-cycle benefits of transmission warm-up technology. For the final rule analysis, the agencies applied off-cycle technologies in the CAFE model. Off-cycle technologies were adopted by all manufacturers, to the maximum extent allowed by regulation. The modeled adoption included

[789] Comments from Environmental Defense Fund, Attachment B, NPRM Docket No. NHTSA-2018-0067-12108, at 70.
[790] Comments from ICCT, NPRM Docket No. NHTSA-2018-0067-11741 full comments, at I-28.
[791] Comments from Fiat Chrysler Automobiles, Attachment 1, NPRM Docket No. NHTSA-2018-0067-11943, at 97.

benefits of transmission warm-up as a menu item. The modeling of off-cycle technologies is further discussed in section [Flexibilities section x] and section [CAFE modeling section x]. We disagree with ICCT and the Auto Alliance comments that transmission warm-up technologies were not included in the NPRM on-cycle analysis. For the NPRM, and for the final rule, the HEG level 2 technology package includes rapid transmission oil warm-up technology.[792] The inclusion of the HEG2 technology package in AT and CVT models accounts for impacts of this technology to performance on the standard test-cycle.

For the final rule making analysis the transmission model paths are shown in Figure VI-15. For the final rule analysis, the baseline-only technologies (MT5, AT5, AT7L2, AT9L2, and CVT) are grayed and are only used to signify initial vehicle transmission configurations. For simplicity, all manual transmissions with five forward gears or fewer are assigned the MT5 technology in the input fleet. Similarly, all automatic transmissions with five forward gears or fewer are assigned the AT5 technology.

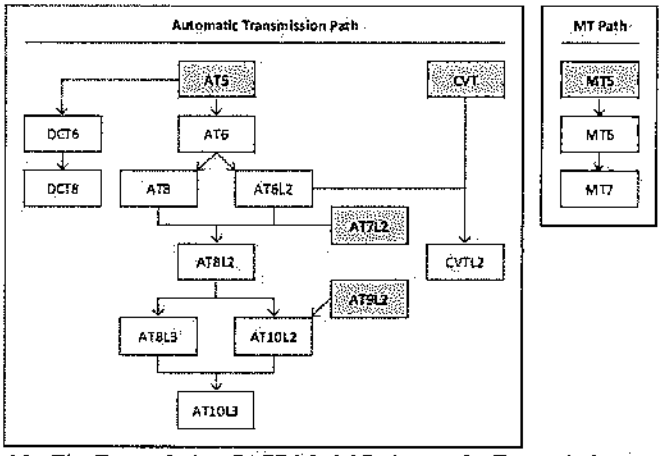

Figure VI-15 - The Transmission CAFE Model Pathways for Transmission Technologies

Since the Manual Transmission path terminates with MT7, the system assumes that all manual transmissions with seven or more gears are mapped to the MT7 technology. Moreover, all dual-clutch (DCT) or auto-manual (AMT) transmissions with five or six forward gears should be mapped to the DCT6 technology, and all DCTs or AMTs with seven or more forward gears should be mapped to DCT8.

The final rule analysis, the naming convention for the transmission technology models was updated to identify better the technologies represented in each transmission. Although the technologies in each transmission configuration were described in the NPRM, there appears to have been confusion among some commenters about the technology content of some

[792] 2015 NAS Report, at 191.

transmission configurations. Some commenters compared the NPRM AT10 to the NPRM AT8, and commented on unexpected differences in effectiveness relative to the differences in transmission gear count.[793] For the given example, the NPRM AT8 represented a baseline 8-speed automatic transmission, with level 1 HEG technology applied, and the NPRM AT10 represented a 10-speed automatic transmission with level 2 HEG technology applied. A direct comparison of gear count would occur by comparing the NPRM AT8L2 to the NPRM AT10. The updated naming convention identifies the transmission technology type, gear count and HEG technology level. Table VI-50Table VI-50 shows the final rule names for transmission models compared to the names used for the NPRM analysis.

Table VI-50 - NPRM transmission model names versus final rule transmission model names

Transmission	NPRM Name	Final rule Name
5-speed automatic	AT5 / 5AU	AT5
6-speed automatic baseline	AT6 / 6AU	AT6
6-speed automatic level 2 HEG	AT6L2 / 6AUp	AT6L2
7-speed automatic level 2 HEG	AT7 / 7AU	AT7L2
8-speed automatic baseline	AT8 / 8AU	AT8
8-speed automatic level 2 HEG	AT8L2 / 8AUp	AT8L2
8-speed automatic level 3 HEG	AT8L3 / 8AUpp	AT8L3
9-speed automatic level 2 HEG	AT9 / 9AU	AT9L2
10-speed automatic level 2 HEG	AT10 / 10AUp	AT10L2
10-speed automatic level 3 HEG	AT10L2 / 10Upp	AT10L3
6-speed dual-clutch	6DCT	6DCT
8-speed dual-clutch	8DCT	8DCT
Continuous variable transmission	CVT	CVT
Continuous variable transmission level 2HEG	CVTL2A/2B	CVTL2
5-speeed manual transmission	MT5	MT5
6-speed manual transmission	MT6	MT6
7-speed manual transmission	MT7	MT7

b) Transmission Analysis Fleet Assignments

The agencies discussed in the NPRM the process for developing the 2016 analysis fleet, including how the agencies weighed using confidential business information versus publicly-releasable sources, the use of compliance data, and decision to use a 2016 analysis fleet over other alternatives.[794] As discussed above, this final rule analysis used the 2017 vehicle fleet as the analysis fleet input, and the agencies followed largely the same process for assigning initial transmission assignments as in the NPRM.

For the 2017 analysis fleet, transmission data was gathered from the manufacturer final model year CAFE compliance submissions to the agencies as well as manufacturer press releases. The data for each manufacturer was used to determine which platforms shared

[793] Comments from CARB, Attachment 2018-10-26 FINAL CARB Detailed Comments on SAFE, NPRM Docket No. NHTSA-2018-0067 at 110-113.
[794] 83 FR 43003.

transmissions and to establish the leader-follower relationships between vehicles. Within each manufacturer fleet, transmissions were assigned unique identification designations based on technology type, drive type, gear count, and technology version. The data were also used to identify the most similar transmission among the Autonomie transmission models, as discussed further below.

The transmission characteristics of vehicles in the analysis fleet show manufacturers use transmissions that are the same or similar on multiple vehicle models. Manufacturers have told the agencies they do this to control component complexity and associated costs for development, manufacturing, assembly, and service. Both the NPRM and final rule analyses account for this sharing. To identify common transmissions, the agencies considered the transmission type (manual, automatic, dual-clutch, continuously variable), number of gears, and vehicle architecture (front-wheel-drive, rear-wheel-drive, all-wheel-drive based on a front-wheel-drive platform, or all-wheel-drive based on a rear-wheel-drive platform). If multiple vehicle models shared these attributes, the transmissions were treated as single group for the analysis. Vehicles in the analysis fleet with the same transmission configuration adopted transmission technology together.

For ATs and CVTs, the identification of the most similar Autonomie transmission model required additional steps beyond just assigning gear count for ATs, or just assigning the CVT model. A review of the age of the transmission design, relative performance versus previous designs, and technologies incorporated was conducted, and the information obtained was used to assign a HEG level. Engineering judgment was used to compare the technologies and performance improvements reported versus descriptions of HEG technology discussed in the NAS report.[795]

In addition, no automatic transmissions in the 2017 analysis fleet were determined to be initially at a HEG Level 3. However, all 7-speed automatic transmissions, all 9-speed automatic transmissions, all 10-speed automatic transmissions and some 8-speed automatic transmissions were found to be advanced transmissions operating at a Level 2 HEG equivalence. All other transmissions were assigned at the minimum level.

c) Transmission Adoption Features

The agencies included several transmission adoption features in the NPRM that have been carried over for the final rule analysis. For a detailed discussion of path logic applied in the final rule analysis, including technology supersession logic and technology mutual exclusivity logic please see [CAFE model documentation paragraph S4.5]

(1) Automatic Transmissions

Automatic transmission technology adoption is defined by path logic and technology availability. The transmission path precludes adoption of other transmission types once a

[795] 2015 NAS Report, at 191.

platform progresses past an AT6. This restriction is used to avoid the significant level of stranded capital that could result from adopting a completely different transmission type shortly after adopting an advanced transmission, which would occur if a different transmission type was adopted after AT6 in the rulemaking timeframe. Stranded capital is discussed in more detail in Section [Stranded Capital Section]. In addition, any automatic transmissions that use HEG3 technology cannot be phased in until the 2020 model year. The technology phase-in year is based on the estimated availability of HEG3 technology from the NAS (2015) report and confidential data obtained from OEM's and suppliers. Finally, all P2HEVs are paired with an AT8 transmission, which is also discussed further in Section [Electrification].

One commenter expressed concern that all P2HEVs were paired with an AT8 transmission, and argued that the full slate of transmission technology should be available for adoption with that powertrain technology.[796] The commenter correctly observed a limit of transmission technologies for use only with the P2HEV technology option; all other HEV based technology options did not have this limitation.

The agencies disagree that a greater variety of transmission technologies are necessary to model the P2HEV technology reasonably. The P2HEV demonstrated limited response to transmission technologies beyond the AT8L2, and access to those technologies were limited to reflect the diminishing returns anticipated for higher gear counts used in conjunction with the P2 system, and trends in industry.[797] Adopting P2HEV to a conventional vehicle provides a significant fuel consumption improvement, agnostic of transmission type, based on our full vehicle simulation results.

(2) Continuously Variable Transmissions

Application of CVTs in the NPRM and final rule analysis was not allowed for high torque vehicle applications. The launch, acceleration, and ratio variation characteristics of powertrains with CVTs may be significantly different than ATs leading to potential consumer acceptance issues and/or complaints. Several manufacturers have told the agencies that they employ strategies that mimic AT shifting under some conditions to address these issues. Some manufacturers have also encountered significant engineering challenges in employing CVTs for use in high torque or high load applications.

In addition, the CVT adoption was limited by technology path logic. CVTs cannot be adopted by vehicles that do not start with a CVT or by vehicles beyond the AT6 in the baseline fleet which have a greater number of gear ratios and therefore increased ability to operate the engine at a highly efficient speed and load. Once on the CVT path the platform is only allowed to apply improved CVT technologies. This restriction is used to avoid the significant level of stranded capital that could result from adopting a completely different transmission type shortly after adopting an advanced transmission, which would occur if a different transmission type was

[796] Comments from Meszler Engineering Services, Attachment 2, NPRM Docket No. NHTSA-2018-0067-11723 at 32.
[797] Greimel, H. "ZF CEO - We're not chasing 10-speeds," Automotive News, November 23, 2014, http://www.autonews.com/article/20141123/OEM10/311249990/zf-ceo:-were-not-chasing-10-speeds.

adopted in the rulemaking timeframe. Stranded capital is discussed in more detail in Section [Stranded Capital Section].

The Alliance of Automobile Manufacturers (hereinafter referred to as the Alliance, or the Auto Alliance) commented that the analysis "appropriately restricts the application of CVT technology on larger vehicles."[798] The agencies concurred with the Auto Alliance's observations and thus the limitations on CVT application were continued in the final rule analysis.

(3) Dual Clutch Transmission

For DCTs, while the structure of the model could allow automatic transmissions to consider applying a DCT, the market data file was used to preclude the application of DCTs to vehicles that had already adopted an automatic transmission with six or more gears (e.g., AT6 through AT10). The model allows baseline vehicles that have DCTs to apply an improved DCT (if opportunities to do so exist), and allows vehicles with an AT5 to consider DCTs. This was done to ensure vehicle functionality is maintained as technologies are applied, and accounts for consumer acceptance issues related to the drivability and launch performance tradeoffs. These issues with DCTs resulted in a low relative adoption rate over the last decade.[799] It also is broadly consistent with manufacturers' technology choices.

(4) Manual Transmissions

Manual transmission technology adoption in the CAFE model remained unchanged from the NPRM and is only limited by the technology path limits discussed above. Manual transmissions cannot be adopted by vehicles that do not start with a manual transmission in the analysis fleet. Manual transmissions cannot select an alternate transmission technology, and may only progress to more advanced manual transmissions. These restrictions are in recognition of the low customer demand for manual transmissions.[800]

d) Transmission Effectiveness Modeling and Resulting Effectiveness Values

For the NPRM and final rule analysis, full vehicle simulation was used to understand how transmissions work within the full vehicle system to improve fuel economy, and how changes to the transmission subsystem influence the performance of the full vehicle system.

The Autonomie tool models transmissions as a sequence of mechanical torque gains. The torque and speed are multiplied and divided, respectively, by the current ratio for the selected operating condition. Furthermore, torque losses corresponding to the torque/speed operating point are subtracted from the torque input. Torque losses are defined based on a three-

[798] Comments from Auto Alliance, Attachment 1, NHTSA-2018-0067-12073, at 142.
[799] "The 2018 EPA Automotive Trends Report," Page 60, figure 4:18, https://www.epa.gov/fuel-economy-trends/download-report-co2-and-fuel-economy-trends, Accessed Aug 23, 2019.
[800] "The 2018 EPA Automotive Trends Report," https://www.epa.gov/fuel-economy-trends/download-report-co2-and-fuel-economy-trends, Accessed Aug 23, 2019.

dimensional efficiency lookup table that has as inputs: input shaft rotational speed, input shaft torque, and operating condition.[801]

The general transmission models are populated with characteristics data to model specific transmissions. Characteristics data are typically provided in the form of tabulated data for transmission gear ratios, maps for transmission efficiency, and maps for torque converter performance, as applicable. The quantity of data needed depends on the transmission technology being modeled. The characteristics data for these models was collected from peer-reviewed sources, transmission and vehicle testing programs, results from simulating current and future transmission configurations, and confidential data obtained from OEM's and suppliers.[802]

The level of HEG improvement applied to a given transmission was modeled by improvements made to the efficiency map of the transmission. As an example, the 8-speed automatic transmission models show how a model can be incrementally improved with the addition of the HEG enhancement. The AT8 is the model of a baseline transmission developed from a transmission characterization report.[803] The AT8L2 has the same gear ratios as the AT8, however the gear efficiency map has been improved to represent application of the HEG level 2 technologies. The AT8L3 models the application of HEG level 3 technologies using the same principle, further improving the gear efficiency map over the AT8L2 improvements.

The NPRM and final rule analysis, using the Autonomie tool, comprehensively simulated each of the 18 transmission technologies. Each transmission was modeled with explicit gear ratios, gear efficiencies, gear spans, adaptive shift logic, and transmission architecture individually for each of the ten vehicle types. The NPRM and final rule analysis clearly showed the specific contributions to effectiveness provided by each transmission technology combination and the associated cost. This provided greater transparency for public review and comment.

The implementation of the full vehicle simulation approach used in the NPRM analysis, and carried forward to the final rule analysis, clearly defines the contribution of individual transmission technologies and separates those contributions from other technologies. This modeling approach comports with the National Academy of Science 2015 recommendation to use full vehicle modeling supported by application of collected improvements at the sub-model level.[804] The approach allows the isolation of technology effects in the analysis which contributes to an accurate cost assessment.

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[801] Detailed discussion of transmission modeling can be found in the ANL documentation at [XX].

[802] Downloadable Dynamometer Database.: https://www.anl.gov/energy-systems/group/downloadable-dynamometer-database, Kim, N., Rousseau, N., Lohse-Bush, H., "Advanced Automatic Transmission Model Validation Using Dynamometer Test Data," SAE 2014-01-1778, SAE World Congress, Detroit, April 2014., Kim, N., Lohse-Bush, H., Rousseau, A., "Development of a model of the dual clutch transmission in Autonomie and validation with dynamometer test data," International Journal of Automotive Technologies, March 2014, Volume 15, Issue 2, pp 263-271.

[803] [Insert AT8 transmission report (FEV) reference]

[804] *2015 NAS Report*, at 292.

This approach was supported by the Auto Alliance, who commented in support of the agencies' explicit and transparent modeling of the cost and effectiveness for each of the transmission technologies. The Alliance contrasted the NPRM approach with the transmission modeling methodology used in the Proposed Determination—which they strongly objected to—which had lumped together fundamentally different transmission technologies into bundles with identical cost and efficiencies, "making it impossible to fully comprehend the rationale" for the Proposed Determination's high effectiveness estimates.[805]

However, other stakeholders were not supportive of the modeling approach used in the NPRM. The Union of Concerned Scientists (UCS) thought a level of abstraction was necessary to account for unpredictability in the market, such as the failure of the dual-clutch transmission to reach widespread use as anticipated in the agencies 2012 analysis for MYs 2017 and later. UCS thought that keeping the transmission technology generalized would avoid the pitfalls of potentially picking the wrong technology leader, but would still predict the general trend of behavior, stating that "[i]ncidentally, this is an example of why we supported EPA's move to a more generic representation of transmissions in its OMEGA modeling."[806]

The agencies disagree with UCS's suggestion to generalize the transmission technology groupings for the analysis. By grouping the technologies into overly broad, generic categories, the analysis loses accuracy on the costs and the effectiveness for specific systems. The OMEGA model used general transmission categories, asked for by UCS's comments, as part of the CO_2 analysis in the [TAR 2015] and in the [Proposed Determination], and the assumptions and limitations were acknowledged at the time.[807,808] One assumption used by the OMEGA model approach was "[t]he incremental effectiveness and cost for all automated transmissions are based on data from conventional automatics."[809] In response, the Alliance observed that the transmission groups used "do not recognize unique efficiencies of different transmission technologies."[810] At the time EPA stated "the potential effectiveness gains between TRX levels, while arising from different technology packages within each transmission type, will be very similar among the transmission types."[811] However, as shown in [Table X] and [Table X], there are nontrivial differences in the costs of different transmission technologies.

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[805] Comments from Alliance of Automobile Manufacturers, NHTSA-2018-0067-12073, at 142.
[806] Comments from Union of Concerned Scientists, NHTSA-2018-0067-12039, at 20-21.
[807] "Midterm Evaluation of Light duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025," Paragraph 5.3.4.2.1, EPA-420-D-16-900, July 2016
[808] "Proposed Determination on the Appropriateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, Technical Support Document," Pages 2-328 - 2-329, EPA-420-R-16-021, November 2016.
[809] "Proposed Determination on the Appropirateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, Technical Support Document," Pages 2-327, EPA-420-R-16-021, November 2016.
[810] "Proposed Determination on the Appropirateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, Technical Support Document," Pages 2-329, EPA-420-R-16-021, November 2016.
[811] "Proposed Determination on the Appropirateness of the Model Year 2022-2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation, Technical Support Document," Pages 2-329, EPA-420-R-16-021, November 2016.

The approach used in the NPRM analysis and this final rule analysis is an evolution of the approach used for the Proposed Determination model, and avoids the issue described above. The NPRM and final rule analyses reduce the span of transmission technology groupings, with the intent to provide an increase in fidelity and precision for cost and performance, as was requested by stakeholders such as the Auto Alliance, while including tools to mitigate market effects, which addresses other concerns such as those expressed by UCS. In the analysis for the final rule the transmissions are grouped by technology type (AT, DCT, CVT, etc.) and gear count (5,6,7, etc.). The level of HEG technology applied as a separate factor further subdivided the transmission groups. Defining technology adoption features addresses the potential for market forces, such as those that affected the sales of DCTs, and supports the narrower technology groupings. Technology adoption features are defined through market research, historic and current fleet composition analysis, and dialogue with manufacturers.

Commenters also provided general comments regarding the values of effectiveness for advanced transmissions used for the NPRM analysis versus values used for the Draft TAR. For example, CARB noted a "2 percent-3 percent lower efficiency assumed for advanced 8- and 9-speed transmissions relative to the data EPA itself previously developed with back to back testing on FCA vehicles,"[812] with similar concerns expressed by other commenters.[813] Meszler Engineering Services wondered "why the AT10 technology was being so widely adopted when its associated benefits appeared negligible for a particular vehicle" and noted "[t]he wide ranging effectiveness estimates were unexpected."[814] Senator Tom Carper also noted "the most advanced eight speed transmission technology are assigned unrealistically low fuel efficiency effectiveness values for some vehicle types."[815]

The Auto Alliance also provided comments with regards to the larger variation of effectiveness values that were of concern to commenters such as Meszler Engineering Services and Senator Tom Carper. The Auto Alliance acknowledged that the use of full vehicle simulation, with more details, results in greater diversity of results. The comment stated, "Over an entire fleet, a more reasonable expectation is that there will be some vehicles with higher fuel economy than expected for a given technology set and some vehicles with a lower fuel economy than expected for a given technology set. As discussed above, these differences arise for a variety of reasons, and cannot simply be attributed to "less than optimal technology integration."[816]

The Auto Alliance also specifically commented on the FCA vehicle study used to support CARB's comment and used to generate the TAR analysis values. The Auto Alliance pointed out

[812] Comments from CARB, Attachment 2018-10-26 FINAL CARB Detailed Comments on SAFE, NPRM Docket No. NHTSA-2018-0067-11873, at 110-113.
[813] Comments from Roush Industries, Attachment 1, NPRM Docket No. NHTSA-2018-0067-11984, at 5; Comments from CARB, Attachment HDS Final Report, NPRM Docket No. NHTSA-2018-0067-11985, at 26, 47.
[814] Comments from Meszler Engineering Services, Attachment 2, NPRM Docket No. NHTSA-2018-0067-11723, at 5-6.
[815] Comments from Senator Tom Carper, Attachment 1, NPRM Docket No. NHTSA-2018-0067-11910, at 4.
[816] Comments from Alliance of Automobile Manufacturers, Attachment 1, NPRM Docket No NHTSA-2018-0067-12385, at 9.

that the vehicles used in the study had other technology differences, however the study still "proceeds to compare the fuel economy of these variants to assert support for its own estimate of transmission effectiveness. This comparison neglects that the 2.4L engines in these variants are not the same and that the variant with the nine-speed transmission was a redesigned vehicle." The Alliance concluded, therefore, that "the Chrysler 200 comparison provided by H-D Systems does not compare a transmission change in isolation from other changes that impact fuel economy and likely overestimates the benefits associated with the transmission change." The Auto Alliance summarized the analysis of the study by noting that "[s]uch differences also impact fuel economy, confounding an analysis which purports to compare the fuel economy benefits associated directly with the transmission."[817]

The agencies agree with the Auto Alliance assessment of the 8- and 9-speed FCA vehicles, and have based analysis inputs on alternate information sources.[818] However, the observations by commenters of a wider range of values for the NPRM effectiveness when compared to the Draft TAR compliance analyses are a direct result of the improvements in modeling approach. As discussed above the NPRM compliance analysis increased the number of transmission technology paths considered by further subdividing the technology groupings. The change resulted in a wider range of effectiveness, as the specific transmission technologies are paired across all the configurations of vehicle technologies. In addition to this greater range, there were also specific effectiveness issues identified for some of the transmission technologies, which are addressed in the sections below.

Commenters may also be observing, with comments like "advanced transmissions have low effectiveness with some vehicles types," an expected effect when an advanced transmission is coupled to an advanced engine. The National Academy of Science, in their 2015 report, noted that "as engines incorporate new technologies to improve fuel consumption, including variable valve timing and lift, direct injection, and turbocharging and downsizing, the benefits of increasing transmission ratios or switching to a CVT diminish."[819] This is not to say that transmissions are not an important technology going forward, but rather a recognition that advanced engines have larger "islands" of low fuel consumption that rely less on the transmission to improve the overall efficiency of the vehicle. Thus, effectiveness percentages reported for transmissions paired with unimproved engines would be expected to be reduced when the same transmission is paired with a more advanced engine.

Commenters also expressed concern for the transmission gear set and final drive values used for the NPRM analysis, or, more specifically, that the gear ratios were held constant across applications. Roush commented that "all transmissions with a given number of ratios (8-speed, 10-speed) maintain the same individual step ratios" and that this would lead to "powertrain inefficiencies and under-predict potential fuel economy benefits."[820] CARB, quoting a report from its contractor, noted that "the final drive ratio was kept constant as powertrains were

[817] Comments from Alliance of Automobile Manufacturers, Attachment 1, NPRM Docket No NHTSA-2018-0067-12385, at 27-28.
[818] [Example of transmission input data references]
[819] [NAS 2015 report]
[820] Comments from Roush Industries, Attachment 1, at 14-15.

changed and that transmission gear ratios were not optimized," and suggested that manufacturers forgoing improvements from gear ratio or final drive ratio changes is unrealistic and results in an underestimation of the benefits from advanced transmissions.[821]

However, the Auto Alliance stated that "[m]anufacturers share major technologies such as transmissions and engines across multiple vehicle models and platforms." The Auto Alliance also supported the agencies' approach of not including final drive ratio changes, particularly when only minor system changes are incurred. The Auto Alliance continued further stating that "[i]n the case of passenger cars, the final drive ratio is frequently the same across multiple models that use the same transmission."[822]

We disagree with Roush, Duleep, and CARB's assessment. It is an observable practice in industry to use a common gear set across multiple platforms and applications. The most recent example is the GM 10L90, a 10-speed automatic transmission that used the same gear set in both pick-up truck and passenger car applications.[823] Optimization of performance is achieved through shift control logic rather than customized hardware for each vehicle line. The use of a single gear set for each transmission technology also supports the overall analysis approach. The level of technology performance modeled must reasonably represent a typical level of performance representative of the industry range of performance. If the systems were over-optimized for our modeling, such as applying a unique gear set for each individual vehicle configuration, the analysis would likely over-predict the reasonably achievable fuel economy improvement for the technology. Over-prediction would be exaggerated when applied under real-world large-scale manufacturing constraints necessary to achieve the estimated costs for the transmission technologies. Accordingly, the agencies used the NPRM approach for the final rule analysis.

Next, in response to comments related to the effectiveness of micro-HEV systems, which are discussed in Section [Micro HEV section], and comments related to the effectiveness of diesel engines, which are discussed in Section [diesel engine section], the agencies took a close look at NPRM effectiveness results. Two issues were identified related to the interaction between Autonomie transmission models and other Autonomie powertrain technology models. First, a logic issue was found in a transmission control subroutine and, second, there was an issue with a sub-model input. While these items were caused by issues in the transmission model sub-systems, the effects manifested in the effectiveness of the micro-HEV systems and the diesel engine systems. Autonomie uses a gearbox transient sub-model to control the simulated state of powertrain components during a transmission event, such as shifting or vehicle starting and stopping. The simulated powertrain component states include conditions such as clutch engagement, or engine operation mode. A detailed discussion of the Autonomie control model can be found [FRM ANL Model Documentation file]. Different versions of the sub-model are

[821] Comments from CARB, NHTSA-2018-0067-11873, at 110.
[822] Comments from Auto Alliance, Attachment 1, NHTSA-2018-0067-12073, at 142.
[823] "GM Global Propulsion Systems - USA Information Guide Model Year 2018" (PDF). General Motors Powertrain. Retrieved 26 September 2019. https://www.gmpowertrain.com/assets/docs/2018R_F3F_Information_Guide_031918.pdf.

used for micro-HEV technologies (12VSS and ISG) than for conventional drivetrains, mild-HEV or Strong-HEV systems.

An issue was found in the control logic used in the micro-HEV version related to the sequence of powertrain component modes during shifting events for automatic transmissions, regenerative braking events for automatic transmissions, and stop start events for manual transmissions. While these issues reduced the effectiveness of the micro-HEV technology in the ANL modeling results, they had very minimal effect on the overall NPRM Analysis. The control logic issue was resolved for the final rule analysis. There also was an issue with the gearbox transient sub-model used for micro HEVs that impacted calculation of the CVT best efficiency operating ratio targets under low torque conditions. This resulted in some negative effectiveness values for certain CVT technology combinations, but had very minimal effect on the overall NPRM results. This software item was also resolved for the final rule analysis.

As discussed in the Autonomie model documentation [FRM ANL Model Documentation file], the full vehicle model is created from a network of subsystem models. The subsystems all interact thru data connections transferring outputs from one subsystem model to the inputs of another. An issue was identified with the definition of the connection between the gearbox transient sub-model for DCT's with diesel engines, which impacted the values provided to the diesel control model. This caused reduced effectiveness values for the diesel engines with DCT in the ANL modeling results, however it had very minimal effect on the overall NPRM analysis. The data connection issue was resolved for the final rule analysis.

Lastly, the agencies received several comments on transmission shifting logic, which are addressed in the following section.

(1) Shift Logic

Transmission shifting logic has a significant impact on vehicle energy consumption and was modeled in Autonomie to maximize the powertrain efficiency while maintaining acceptable drive quality. The logic used in the Autonomie full vehicle modeling relied on two components: (1) the shifting controller, which provides the logic to select appropriate gears during simulation; and (2) the shifting initializer, an algorithm that defines shifting maps (i.e., values of the parameters of the shifting controller) specific to the selected set of modeled vehicle characteristics and modeled powertrain components.[824]

(a) Shifting Controller

The shift controller is the logic that governs shifting behavior during simulated operation. The shift controller performance was informed by inputs from the model. The inputs included: specific engine or transmission used, and instantaneous conditions in the simulation. Instantaneous conditions included values such as vehicle speed, driver demand and a shifting map unique to the full vehicle configuration.[825] The shift controller logic was consistently applied for all vehicles simulated.

[824] *See* [FRM ANL Model Documentation file].
[825] *See* [FRM ANL Model Documentation file].

Although no comments were received specifically on shift control logic, the agencies tracked several effectiveness concerns identified by commenters back to how the agencies modeled some transmissions paired with turbocharged engines. Meszler Engineering Services discussed an unexpected range of effectiveness observed for transmissions when coupled to different engine technologies, and concluded that "[m]oreover, the variation across technology combinations is markedly different."[826] Senator Carper's comments mirrored Meszler's, noting that "the more expensive version of an engine technology (TURBO2), which would be expected to be more fuel-efficient, was instead assigned a negative fuel-efficiency value for some types of vehicles."[827] The Senator also observed the same phenomenon for cooled exhaust gas recirculation (CEGR I), which "was assigned a fuel-efficiency effectiveness of at or near zero." Similarly, UCS noted that "many simulations of improved transmissions and turbocharged engines show little incremental improvement over less complex technologies."[828]

In response to the comments, the agencies conducted an in-depth review of these technology combinations. The agencies determined the minimum lugging speed for turbocharged engines, which controls the minimum engine speed allowed before down-shifting, caused the observed behavior. The issue was isolated to some combinations of advanced transmissions and turbo charged engines. For the final rule analysis, a modification was made to the shift controller logic of transmissions coupled to turbocharged engines. Specifically, the minimum lugging speed allowed for turbocharged engines was increased in the shift controller. An increase in lugging speed increases the minimum speed at which the shift controller will allow the engine to operate before down-shifting, resulting in increased operation in better efficiency regions of the engine map.[829] The updated lugging speeds are based on ANL benchmarking data of the 2017 F150.[830] The updated values are shown in Table VI-51, the lugging speeds for naturally aspirated engines are shown as reference and remain unchanged from the NPRM.

Table VI-51 - Lugging speeds for transmissions in the final rule analysis

	5-speed	6-speed	7-speed	8-speed	9-speed	10-speed
Naturally Aspirated Lugging speed (rad/s)	140	130	120	110	110	110
Turbocharged Lugging speed (rad/s)	140	130	130	130	130	130

[826] Comments from Meszler Engineering Services, Attachment 2, NPRM Docket No. NHTSA-2018-0067-11723, at 5-6.
[827] Comments from Senator Tom Carper, Attachment 1, NPRM Docket No. NHTSA-2018-0067-11910, at 4.
[828] Comments from UCS, Attachment 1, NPRM Docket No. NHTSA-2018-0067-12039, at 32.
[829] *See* [FRIA Paragraph XX] for more details on lugging speed.
[830] NHTSA Benchmarking, "Laboratory Testing of a 2017 Ford F-150 3.5 V6 EcoBoost with a 10-speed transmission." DOT HS 812 520.

(b) Shift Initializer

As defined above, the shifting initializer is an algorithm that defines shifting maps (i.e., values of the parameters of the shifting controller) specific to the selected set of modeled vehicle characteristics and modeled powertrain components.

Commenters stated that the model did not customize shifting maps for each transmission application. Roush Industries commented, "[t]he 2018 PRIA analysis assumes that all transmissions with a given number of ratios maintain the same individual step ratios and shift maps."[831] Roush also commented that the effectiveness of transmissions were understated due to inaccurate transmission maps or "the lack of vehicle system optimization and calibration."[832] UCS stated that the "transmission shift strategy does not deploy gear-skipping or other more modern control strategies."[833] Duleep provided similar comments to Roush, observing that the Autonomie models "do not optimize engine efficiency after most changes in tractive load because the model employs fixed shift points, gear ratios, and axle ratios."[834] And finally, CARB expressed that "[f]or the Autonomie modeling, a fixed final drive ratio was utilized and, presumably, a fixed shift logic based on the selected transmission."[835]

The commenters seem to conflate the practice in the analysis of using the same gear sets across vehicle configuration with using the same shift maps. As commenters stated, they assumed the same maps were applied across vehicle models. However, the shift initializer routine was run for every unique Autonomie full vehicle model configuration and generated customized shifting maps. The algorithms' optimization was designed to balance minimization of energy consumption and vehicle performance.[836] This balance was necessary to achieve the best fuel efficiency while maintaining customer acceptability by meeting performance neutrality requirements [see Performance Neutrality section].

While discussing shift logic, commenters also expressed concern about the capturing of fuel efficiency losses associated with shifting events. Roush stated, "[t]he 2018 PRIA transmission modeling does not accurately capture the losses and FE penalty associated with a shift event."[837] We disagree with this statement. While losses associated with a shifting event are not modeled as a single factor, the mechanisms that cause the loss are appropriately incorporated in the Autonomie transmission models. The automatic transmission models have an associated torque converter model.[838] The torque converter model is designed to simulate the inertial and torque loads imposed on an engine because of shift events. Other clutch-based transmission models, MTs and DCTs, apply a general loss of efficiency across transmission efficiency maps to account for losses due to shift events.

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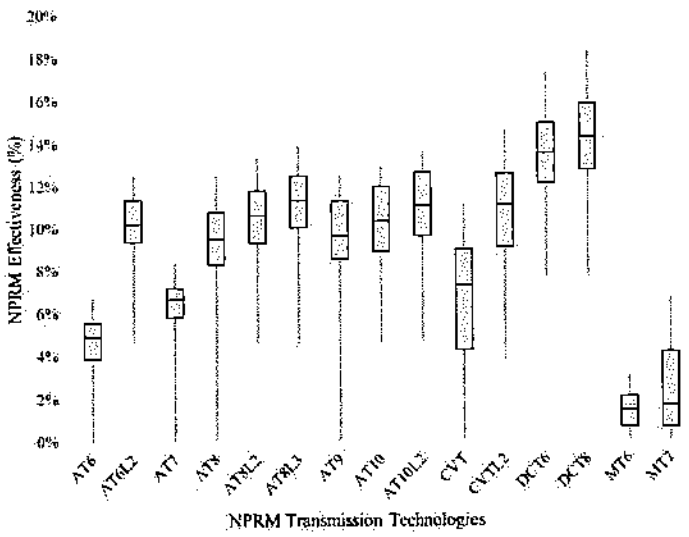
[831] Comments from Roush Industries, Attachment 1, at 14-15.
[832] Comments from Roush Industries, Attachment 1, at 5.
[833] Comments from UCS, Attachment 1, NPRM Docket No. NHTSA-2018-0067-12039, at 23.
[834] Comments from K. Gopal Duleep, Attachment 1, NPRM Docket No. NHTSA-2018-0067-12395, at 4-5.
[835] Comments from CARB, Attachment 2018-10-26 FINAL CARB Detailed Comments on SAFE, NPRM Docket No. NHTSA-2018-0067-11873, at 185.
[836] *See* [FRM ANL Model Documentation file].
[837] Comments from Roush Industries, Attachment 1, NPRM Docket No. NHTSA-2018-0067-11984, at 14-15.
[838] *See* [FRM ANL Model Documentation file].

(2) Transmission Effectiveness Values

The NPRM technology effectiveness modeling results showed that the effectiveness of a technology often varies with the type of vehicle and the other technologies that are on the vehicle. Figure VI-16 shows the range of effectiveness for each automatic transmission technology across the range of vehicle types and technology combinations in the NPRM analysis. The data reflect the change in effectiveness for applying each transmission technology by itself while all other technologies are held unchanged. The effectiveness improvement range is over a 5-speed automatic transmission.

Figure VI-16 - Range of Effectiveness for Transmission Technologies in NPRM Analysis



(a) Automatic Transmissions

Regarding AT effectiveness values, commenters pointed out the unusually high level of effectiveness displayed by the AT6L2 transmission. ICCT and UCS both specifically expressed

concern with the effectiveness of the AT6L2 compared to other advanced transmissions.[839,840] The performance of the AT6L2 was central to ICCT's analysis of the NPRM inputs, which highlighted the AT6L2 models' performance, showing the cost versus effectiveness of the AT6L2 outperformed more advanced transmission options.[841]

Evaluation of the AT6L2 transmission model in response to these comments revealed an overestimated efficiency map was developed for the NPRM model. The high level of efficiency assigned to the transmission surpassed benchmarked advanced transmissions.[842] To address the issue, the agencies replaced the effectiveness values of the AT6L2 model for the final rule analysis with AT7L2 effectiveness values.

The updated estimate of effectiveness is supported by values shown in the NAS 2015 analysis.[843] The study estimated the difference in effectiveness between a 6-speed automatic transmission and a 7-speed automatic transmission of approximately the same technology level to be 0.8 percent. The difference is reduced further when application of high efficiency gear box technology ranges of effectiveness is applied. Because the 7-speed automatic transmission and the advanced 6-speed automatic transmission technologies are parallel on the technology tree, the agencies felt using the same effectiveness value was reasonable and appropriate.

Commenters also pointed out a lack of skip-shift logic used in the NPRM analysis, and an increase in the shift busyness observed for the high gear count transmissions. Roush commented on the NPRM analysis "not incorporating the concept of 'Skip shifting' which is important for reducing shift busyness and increasing FE especially in vehicles equipped with transmission with a large number of ratios (8-10)."[844] Both CARB and UCS repeated similar concerns.[845]

After consideration of the comments and re-evaluation of the NPRM results, the agencies concurred with the commenters. The lack of skip-shift logic and increased shift busyness can result in lower overall efficiency and decreased consumer acceptance. For the final rule analysis, a skip-shift logic was applied to the 10 speed automatic transmissions. The logic was based on

Commented [A250]: REVISE: Although the comments from ICCT and UCS do indeed highlight the (formerly) strangely high effectiveness of the AT6L2 trans, the UCS comment also points out the issue that the CAFE model is inappropriately discarding less costly, higher efficiency technology in favor of more costly, lower efficiency technology. Hopefully NHTSA has also fixed that issue.

Commented [A251]: REVISE: The footnote should cite exactly what transmission is being referring to (noting missing reference in the footnote).

Commented [A252]: REVISE: Additional explanation for why skip-shift logic was only applied to ten speeds. Nines and eights, at least, also tend to skip as needed.

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[839] Comments from International Council on Clean Transportation, Attachment 3, NPRM Docket No. NHTSA-2018-0067-11741, at I-26, I-64 (""However, the impact of adding level 2 transmission efficiency technologies varies wildly and produces absurd results. A 6-speed AT6L2 Is modeled as much more efficient (12.0% improvement) than a comparable 8-speed AT8L2 (9.1%) and even slightly more efficient than a comparable 10-speed AT10L2 (11.5%).")%).".

[840] Comments from Union of Concerned Scientists, Attachment 1, NPRM Docket No. NHTSA-2018-0067-12039, at 32. ("[I]n the NPRM analysis, 0 percent of vehicles had an AT6L2 transmission while 52.4 percent adopted AT10L2 transmissions, even though the latter supplies virtually identical modeled efficiency.")".

[841] Comments from International Council on Clean Transportation, Attachment 3, NPRM Docket No. NHTSA-2018-0067-11741, at I-64 – I-65.

[842] [Reference to current efficiency benchmark for AT6].

[843] 2015 NAS Report, at page 189.

[844] Comments from Roush Industries, Attachment 1, at 14-15.

[845] Comments from CARB, Attachment 2018-10-26 FINAL CARB Detailed Comments on SAFE, NPRM Docket No. NHTSA-2018-0067-11873, at 110-113 ("Rogers found that the modeling did not consider 'skip-shifting' where a transmission can upshift or downshift in a non-sequential manner". Comments from UCS, Attachment 1, NPRM Docket No. NHTSA-2018-0067-12039, at 23 "including that ANL's transmission shift strategy does not deploy gear-skipping").".

the baseline 2017 Ford F150 10-speed transmission benchmarking performed by ANL.[846] The introduction of the skip-shift logic impacted effectiveness and reduced the number of shifts by 23 percent for the 10-speed automatic transmission over the UDDS cycle.[847]

In the NPRM analysis, transmission gear spans increased as the number of gears increased.[848] However, to address further the comments related to optimization, the gear span of the AT10L3 was increased over the AT10L2, based on gear span data for the Honda 2018 10-speed transmission.[849] The AT10L3 span was increased to 10.10 in the final rule analysis from 7.34 in the NPRM analysis. However, the efficiency map for the AT10L3 remained the same for the final rule analysis.[850]

Finally, in the agencies' review of NPRM model inputs, a weight discrepancy for the AT10 transmissions was identified. The weight assigned to the AT10 transmission in the NPRM analysis was too high. The weights were corrected for the final rule analysis. The AT10 transmission weights were reduced by 20-45 kg, depending upon vehicle type.[851]

The AT effectiveness values used for the final rule analysis can be seen in Figure VI-17. For automatic transmission technologies, the effectiveness improvement range is relative to a 5-speed automatic transmission. The new effectiveness values are a result of the aforementioned changes implemented to address comments. To summarize, the changes included an adjustment to the modeled effectiveness of the AT6L2, the use of skip-shift logic on the 10-speed transmissions, and the increase of the AT10L2 gear span.

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[846] NHTSA Benchmarking, "Laboratory Testing of a 2017 Ford F-150 3.5 V6 EcoBoost with a 10-speed transmission." DOT HS 812 520.
[847] *See* [FRM ANL Model Documentation file]. This update reduced the number of shift events from 231 to 178.
[848] *See* [FRM ANL Model Documentation file].
[849] Sugino, S., SAE Internation Presentation., "ALL-NEW HONDA 10-SPEED FWD TRANSMISSION.". November 2017.
"*2018 Honda Odyssey Press Kit – Overview*.", Internet: Honda News, https://hondanews.com/en-US/releases/2018-honda-odyssey-press-kit-overview, accessaccessed October 8, 2019.
[850] *See* [FRM ANL Model Documentation file].
[851] *See* [FRIA discussion on transmission weights].

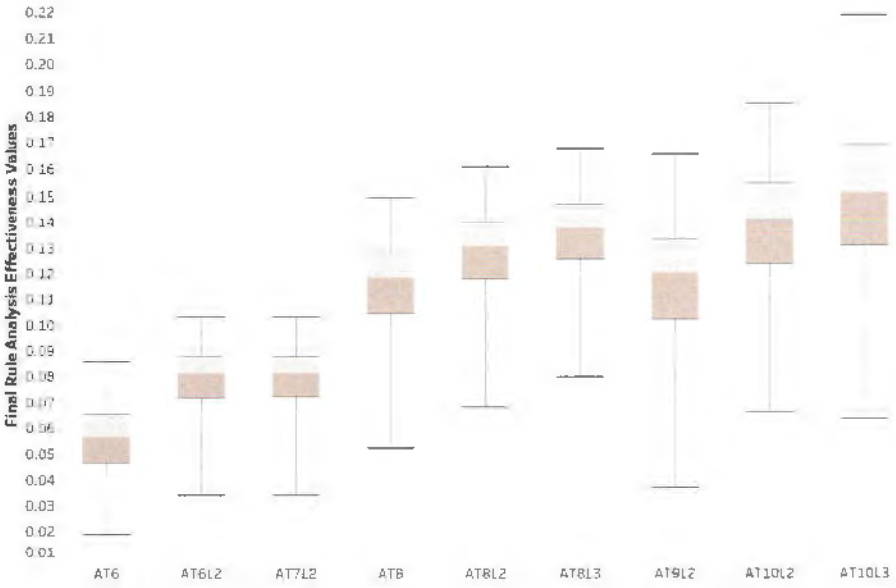


Figure VI-17 - Effectiveness of Automatic Transmissions in the Final Rule Analysis.

Figure VI-17 shows the automatic transmission's effectiveness increases progressively in a logical order and behaves in an expected manner. Gains in effectiveness can be observed increasing as gear count increases, and as HEG levels increase. The effects of diminishing returns can be observed as gear count reaches higher levels, and effectiveness effects for increased gear count are reduced. This agrees with observed data reported by the NAS and industry stake holders.[852] [853]

Commented [A253]: REVISE: Data shown for the nine is unexpected, and should be double-checked. Perhaps because it's only used in the initial baseline fleet, it doesn't matter that much.

(b) Continuously Variable Transmissions

For CVTs, the agencies also identified a discrepancy with the NPRM CVT weights. The weight assigned to the CVT class during the NPRM analysis was incorrect. Corrected values were assigned for the final rule analysis. The CVT weights were reduced by 9-10 kg based on vehicle type.[854]

[852] 2015 NAS Report, at 175.
[853] Greimel, H. ., "ZF CEO - We're not chasing 10-speeds," Automotive News, November 23, 2014, http://www.autonews.com/article/20141123/OEM10/311249990/zf-ceo:-were-not-chasing-10-speeds.
[854] *See* [FRIA discussion on transmission weights].

The CVT effectiveness values used for the final rule analysis can be seen in Figure VI-18, shown as an effectiveness improvement over a 5-speed automatic transmission. The effectiveness values were not changed significantly from the values used in the NPRM analysis.

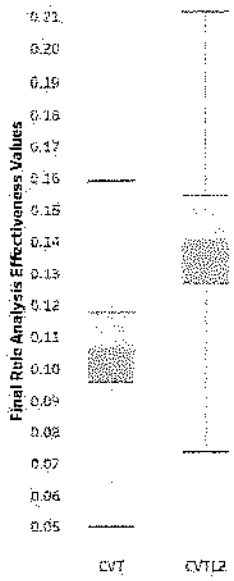
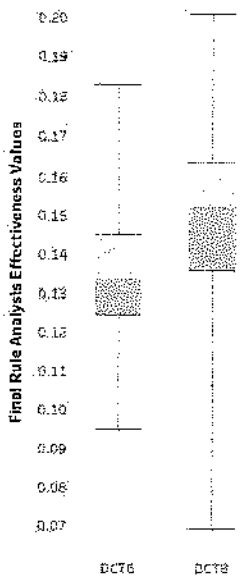


Figure VI-18 – Effectiveness of Continuously Variable Transmissions for Final Rule Analysis

(c) Dual Clutch Transmissions

The DCT effectiveness values used for the final rule analysis can be seen in Figure VI-19, shown as an effectiveness improvement over a 5-speed automatic transmission. The effectiveness values were not changed significantly from the values used in the NPRM analysis.

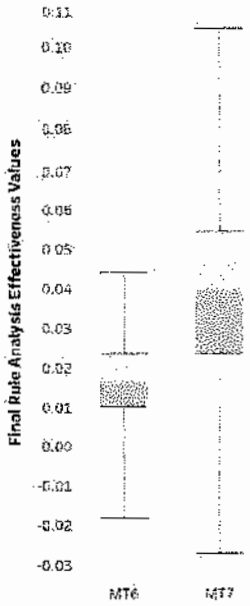
Figure VI-19 – Effectiveness of Dual Clutch Transmissions for Final Rule Analysis



(d) Manual Transmission

The MT effectiveness values used for the final rule analysis can be seen in Figure VI-20, shown as an effectiveness improvement over a 5-speed manual transmission. The effectiveness values were not changed significantly from the values used in the NPRM analysis.

Figure VI-20 – Effectiveness of Manual Transmissions for Final Rule Analysis



e) Transmission Costs

For the NPRM, the transmission technology costs used as inputs for the CAFE model were retail price equivalent costs with learning curves applied. For a complete discussion on how the retail price equivalent and learning effects were applied to direct manufacturing costs see Sections [how we determined technology costs]. The direct manufacturing costs for the transmission technologies used in the NPRM were derived from technical sources and manufacturer's CBI.[855]

Table VI-52Table VI-52 below shows the relative costs of the transmissions used in the NPRM analysis including learning and retail price equivalent.

Table VI-52 - Summary of Relative Transmission Technology Cost vs. Basic Transmission, including Learning Effects and Retail Price Equivalent

Name	Technology Pathway	C-2017	C-2021	C-2025	C-2029
MT5	Manual Transmission	$ -	$ -	$ -	$ -

[855] [NPRM transmission cost references]

MT6	Manual Transmission	$ 359.92	$ 346.99	$ 338.66	$ 333.62
MT7	Manual Transmission	$ 760.72	$ 596.88	$ 514.71	$ 460.49
AT5	Automatic Transmission	$ -	$ -	$ -	$ -
AT6	Automatic Transmission	$ (21.20)	$ (21.17)	$ (21.15)	$ (21.15)
AT6L2	Automatic Transmission	$ 496.02	$ 385.75	$ 356.82	$ 343.77
AT7L2	Automatic Transmission	$ 66.67	$ 51.85	$ 47.96	$ 46.21
AT8	Automatic Transmission	$ 105.71	$ 105.56	$ 105.44	$ 105.42
AT8L2	Automatic Transmission	$ 426.75	$ 331.88	$ 306.99	$ 295.76
AT8L3	Automatic Transmission	$ 673.95	$ 524.13	$ 484.83	$ 467.09
AT9L2	Automatic Transmission	$ 230.63	$ 179.36	$ 165.91	$ 159.84
AT10	Automatic Transmission	$ 230.63	$ 179.36	$ 165.91	$ 159.84
AT10L2	Automatic Transmission	$ 477.83	$ 371.60	$ 343.74	$ 331.17
CVTL2B	Automatic Transmission	$ 430.97	$ 411.83	$ 398.64	$ 388.43
DCT6	Sequential Transmission	$ 29.37	$ 29.33	$ 29.30	$ 29.29
DCT8	Sequential Transmission	$ 693.34	$ 692.36	$ 691.62	$ 691.47
CVT	CVT	$ 246.08	$ 235.16	$ 227.62	$ 221.79
CVTL2A	CVT	$ 430.97	$ 411.83	$ 398.64	$ 388.43

(1) Automatic Transmissions

Several comments were received on technology costs, or cost effectiveness. Meszler Engineering Services noted that "AT10L2 (level 2 ten-speed automatic) transmission technology is another example of an end-of-path technology with very poor cost effectiveness relative to other transmission options."[856] A cost analysis by ICCT also showed relative costs of transmission technologies may not be in line with the modeled effectiveness.[857]

The agencies conducted a review of transmission costs in response to the comments. For the final rule analysis, adjustments were made to costs of the AT6L2, AT7L2, AT9L2, AT10L2, and the AT10L3. The costs were adjusted based on reviewing the recommended relative costs discussed in the NAS 2015 report. Table VI-53 shows the cost for the automatic transmissions in the final rule analysis.

The direct manufacturing cost (DMC) estimate for the AT6 is drawn from Table 5.7 of the NAS report given in 2017 dollars and relative to a AT5/AT4. The DMC estimate for the AT6L2 is based on the cost of the AT6 with HEG level 2 technology costs applied. This cost change is applied in accordance with the effectiveness adjustment made for the AT6L2.

A DMC estimate for the AT7 was drawn from Table 5.9 of the NAS report and was based on the cost of a system already equipped with HEG technology. The DMC estimate was

[856] Comments from Meszler Engineering Services, Attachment 2, NPRM Docket No. NHTSA-2018-0067-11723, at33.
[857] Comments from International Council on Clean Transportation, Attachment 3, NPRM Docket No. NHTSA-2018-0067-11741, at I-64.

given in 2007 dollars and relative to an AT5/AT4. The new DMC replaces the DMC from the NPRM, which did not account for the HEG technology.

The DMC for the AT9 technology was drawn from Table 8A.2a of the NAS (2015) report and per the NPRM description of the technology made relative to the AT8L2. The AT9 is assumed to have at least the level 2 HEG technology applied. The NPRM analysis assumed the AT9 cost was only relative to the AT8 and did not account for the cost of the HEG technology.

The DMC for the AT10 technologies was drawn from Table 8A.2a of the NAS report and per the NPRM description of the technology made relative to the AT8L2. The AT10L2 is assumed to have at least the level 2 HEG technology applied. The AT10L3 has the HEG3 technology applied. The NPRM analysis assumed the AT10 costs were only relative to the AT8 and did not account for the cost of the HEG technology.

Table VI-53 - Summary of Absolute Automatic Transmission Technology Cost, including Learning Effects and Retail Price Equivalent for the Final Rule Analysis

Name	Technology Pathway	C-2017	C-2021	C-2025	C-2029
AT5	Automatic Transmission	$ 2,085.30	$ 2,085.30	$ 2,085.30	$ 2,085.30
AT6	Automatic Transmission	$ 2,063.19	$ 2,063.19	$ 2,063.19	$ 2,063.19
AT6L2	Automatic Transmission	$ 2,397.50	$ 2,323.16	$ 2,303.65	$ 2,294.85
AT7L2	Automatic Transmission	$ 2,351.16	$ 2,292.16	$ 2,276.53	$ 2,269.53
AT8	Automatic Transmission	$ 2,195.51	$ 2,195.32	$ 2,195.18	$ 2,195.15
AT8L2	Automatic Transmission	$ 2,530.24	$ 2,431.30	$ 2,405.33	$ 2,393.61
AT8L3	Automatic Transmission	$ 2,787.99	$ 2,631.74	$ 2,590.74	$ 2,572.25
AT9L2	Automatic Transmission	$ 2,659.49	$ 2,531.80	$ 2,498.29	$ 2,483.17
AT10L2	Automatic Transmission	$ 2,659.49	$ 2,531.80	$ 2,498.29	$ 2,483.17
AT10L3	Automatic Transmission	$ 2,917.97	$ 2,737.81	$ 2,684.21	$ 2,662.29

(2) Continuously Variable Transmissions

No adjustments were made to the NPRM costs of the CVT technologies for the final rule analysis. Table VI-54 shows the cost for the CVT's in the final rule analysis.

Table VI-54 - Summary of Absolute Transmission Cost, including Learning Effects and Retail Price Equivalent for the Final Rule Analysis

Name	Technology Pathway	C-2017	C-2021	C-2025	C-2029
CVT	CVT	$ 2,341.87	$ 2,330.48	$ 2,322.63	$ 2,3165.55
CVTL2	CVT	$ 2,534.64	$ 2,514.69	$ 2,500.94	$ 2,490.29

(3) Dual Clutch Transmissions

The agencies received one comment on cost learning (reduction) over time for DCT technologies. Roush Industries "believes that the [actual] learning factors for such systems are significantly better than those estimated by either the 2018 PRIA or the 2016 Draft TAR." They supported this position because "eight-speed DCTs (DCT8) are currently in production (MY2018), with quantities increasing significantly,"[858] but provided no specific supporting data.

The current learning curve for the DCT technologies was established based on recommendations from the NAS 2015 report and on CBI data collected from manufacturers and suppliers. Since Roush did not supply any data to support its comment, the agencies decided it was reasonable to make no change to the DCT learning curve for the final rule analysis. Table VI-55 shows the cost for the DCTs in the final rule analysis.

Table VI-55 - Summary of Absolute Transmission Cost, including Learning Effects and Retail Price Equivalent for the Final Rule Analysis

Name	Technology Pathway	C-2017	C-2021	C-2025	C-2029
DCT6	Sequential Transmission	$ 2,115.92	$ 2,115.88	$ 2,115.84	$ 2,115.84
DCT8	Sequential Transmission	$ 2,654.56	$ 2,653.75	$ 2,653.15	$ 2,653.02

(4) Manual Transmissions

No adjustments were made to the NPRM costs of the manual transmission technologies for the final rule analysis. Table VI-56 shows the cost for the MTs in the final rule analysis.

Table VI-56 - Summary of Absolute Transmission Cost, including Learning Effects and Retail Price Equivalent for the Final Rule Analysis

Name	Technology Pathway	C-2017	C-2021	C-2025	C-2029
MT5	Manual Transmission	$ 1,563.97	$ 1,563.97	$ 1,563.97	$ 1,563.97
MT6	Manual Transmission	$ 1,939.24	$ 1,925.76	$ 1,917.08	$ 1,911.82
MT7	Manual Transmission	$ 2,357.13	$ 2,186.30	$ 2,100.64	$ 2,044.10

3. Electric paths

Electrification includes a large set of technologies that share the common element of using electrical power for certain vehicle functions that were traditionally powered mechanically by engine power. Electrification thus can range from electrification of specific accessories (for example, electric power steering to reduce engine loads by eliminating parasitic loss) to electrification of the entire powertrain (as in the case of a battery electric vehicle).

[858] Comments from Roush Industries, Attachment 1, NPRM Docket No. NHTSA-2018-0067-11984, at 14-15.

Electrified vehicles are considered, for this analysis, to mean vehicles with a fully or partly electrified powertraiu. These include several electrified vehicle categories, including: battery electric vehicles (BEVs), which have an all-electric powertrain and use only batteries for propulsion energy; plug-in hybrid electric vehicles (PHEVs), which have a primarily electric powertrain and use a combination of batteries and an engine for propulsion energy; and hybrid electric vehicles (HEVs), which use electrical components and a battery to manage power flows and assist the engine for improved efficiency and/or performance. HEVs are further divided into strong hybrids (including P2 and power-split hybrids) that provide strong electrical assist and in many cases, can support a limited amount of all-electric propulsion, and mild hybrids (such as belt integrated starter generator (BISG) hybrids, crankshaft integrated starter generator (CISG) hybrids, and 48V mild hybrids) that typically provide only engine on/off with minimum electrical assist.

Fuel cell electric vehicles (FCEVs) are also another form of electrified vehicle having a fully electric powertrain, and are distinguished by the use of a fuel cell system rather than grid power as the primary energy source.

The factors that influence the cost and effectiveness of electrification technologies are their components. These include: energy storage components such as battery packs; propulsion components such as electric motors; and power electronics components, such as inverters and controllers, that process and route electric power between the energy storage and propulsion components. For the purpose of this analysis, these components are divided into battery components and non-battery components.

Battery components have a strong influence on the cost of electrified vehicles.[859] Because developments in battery technology may apply to more than one category of electrified vehicles, they are discussed collectively in [Battery Section]. That section details battery-related topics that directly affect the specification and costing of batteries for all types of electrified vehicles, such as usable capacity, durability, thermal management, and pack topology, among others.

Non-battery components also have an influence on both the cost and effectiveness of electrified vehicles. Non-battery technologies are important to understanding the differences in architecture among electrified vehicles. Non-battery components largely consist of propulsion components and power electronics.

Propulsion components typically include one or more electric machines (an umbrella term that includes what are commonly known as motors, generators, and motor/generators). Depending on how they are employed in the design of a vehicle, electric machines commonly act as motors to provide propulsion, and/or act as generators to enable regenerative braking and conversion of mechanical energy to electrical energy for storage in the battery.

[859] Battery costs are not necessarily a strong influence on fuel Cell Electric Vehicles, where the cost of the fuel cell technology has a larger influence.

The two main types of electric machines currently seen in production electrified vehicles are permanent-magnet motors (also known as synchronous motors) and induction motors (also known as asynchronous motors). Although the permanent-magnet motors used in electrified vehicles are sometimes called brushless direct-current (DC) motors, these as well as induction motors are powered by alternating current (AC), which must be converted from DC battery current by an inverter.

In the duty cycles typical of electrified vehicle applications, permanent-magnet motors have certain advantages in energy efficiency due in part to the presence of integral permanent magnets to generate part of the magnetic field necessary for operation. However, these magnets add to manufacturing cost, particularly when they contain rare earth elements. In contrast, induction motors use copper windings to generate all of the magnetic field and can be manufactured without rare earth elements. Although the windings are significantly less costly than magnets, generation of the field in the windings is subject to additional winding losses that are not present in permanent magnet motors.

"Power electronics" refers to the various components that control or route power between the battery system and the propulsion components, and includes components such as: motor controllers, which issue complex commands to control torque and speed of the propulsion components precisely; inverters and rectifiers, which convert and manage DC and AC power flows between the battery and the propulsion components; onboard battery chargers, for charging the BEV or PHEV battery from AC line power; and DC-to-DC converters that are sometimes needed to allow DC components of different voltages to work together.

Controllers are electronic devices that implement control algorithms that control power flows through the electrified powertrain. Motor controllers are responsible for issuing the complex commands that precisely control torque and speed of the propulsion motor. A primary task of this controller is to determine the exact frequency of alternating current necessary for the motor to deliver the demanded speed and torque, and to control the inverter to provide it. A supervisory controller is another form of controller that implements higher-level vehicle control algorithms, including issuing high-level torque and speed commands to the motor controller. Supervisory controllers are not unique to electrified powertrains, and may be functionally integrated with other component controllers. Compared to other power electronics components, controllers are not typically large consumers of energy, but can benefit from cost reductions applicable to other components.

Inverters are power conditioning devices that manage electrical power flows between the battery and propulsion motors. While all batteries are direct current (DC) devices, modern traction motors operate on alternating current (AC) and therefore require an inverter capable of converting DC to AC of widely variable frequencies at variable power levels. As implemented in an electrified vehicle, the component commonly known as an inverter may also act as a rectifier, which converts AC to DC to send energy to the battery.

Onboard chargers are charging devices permanently installed in electrified vehicles to allow charging from grid electrical power. Onboard chargers travel with the vehicle and are distinct from stationary charging equipment. Level 1 charging refers to charging powered by a

standard household 110-120V AC power outlet. Level 2 charging refers to charging at 220-240V AC power.

Many systems require DC-to-DC converters to allow DC components of different voltages to work together. These converters do not convert between AC and DC, but instead step up (or down) the DC voltage between two or more components or subsystems, either unidirectional or bi-directionally. One common application of a DC-to-DC converter is to allow low-voltage accessories to be powered by energy from the high-voltage battery. Although many current production electrified vehicles retain a low-voltage battery to power accessories, a buck converter is needed to keep the low-voltage battery charged in the absence of an engine-driven alternator, and can supplement power to the accessories. Another purpose of a DC-to-DC converter is to allow certain powertrain components to operate at their optimum voltage rather than being tied to the voltage of the high voltage battery.

The agencies included a more extensive overview of charging technology and the state of charging infrastructure in the NPRM and PRIA, however, this was purely qualitative because charging was not accounted for in any respect in the NPRM analysis. The Alliance commented that "[w]hile the costs of installing chargers and charger convenience were not taken into account within the Volpe model…these factors will continue to have an impact on the overall penetration of electrification technologies that the market will be willing to accept."[860] In contrast, the National Coalition for Advanced Transportation (NCAT) commented that the qualitative discussion overstated the risks and understated the benefits of electric vehicle charging.[861] Specifically, NCAT took issue with the characterization of potential risks of charging to the electric grid, stating that "the PRIA's focus on worst case hypotheticals does not reflect the current capabilities of the grid, nor the dynamic nature of EV charging to mitigate any potential negative impacts. In both in the short-term and long-term, the impact of EVs with respect to the electric grid would have a net-positive impact to society, including the EV owners and utility customers broadly." NCAT also commented that "[w]hile substantial investments in EV infrastructure have and will be made, the costs and benefits to consumers must be put into the appropriate context." NCAT cited two studies for the proposition that the average lifetime distribution electric vehicle infrastructure impact is about $80-$90 per electric vehicle sold, with the adoption of time of use rates and assuming a diversity of charging rates. NCAT also cited the California Public Utilities Commission 2016-2017 Electric Vehicle Load Research Report in support of their statement that the additional service and distribution system upgrades due to additional plug-in electric vehicle load is minimal, as "of the approximately 275,000 [electric] vehicles estimated to be on the road as of October 2017 in the service areas of California's three investor-owned utilities, only 460, or 0.16 percent required a service line or distribution system upgrade solely to support the plug-in electric vehicle load at their residential charging location."[862]

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[860] NHTSA-2018-0067-12073.
[861] NHTSA-2018-0067-11969.
[862] Citing Joint IOU Electric Vehicle Load Research Report (December 29, 2017), pp. 1-2, 12, available at http://www.cpuc.ca.gov/zev/ (2016-2017 Load Research Report).

The agencies agree that adding electric vehicle infrastructure will require additional costs, and information about what that cost is and how it can or should be accounted for in the analysis is helpful for commenters to submit in order to put those considerations in the appropriate context. For this final rule, the agencies did not incorporate any costs related to electric vehicle charging infrastructure in the technology compliance analysis because those costs are separate from the costs that manufacturers and consumers would directly incur from a manufacturer transitioning part of their fleet to plug-in electric vehicles and consumers paying for those vehicles, even though local electric ratepayers will in all likelihood pay higher rates to upgrade local power grids to accommodate any widespread adoption of electrified vehicles. Accordingly, this means that the actual costs associated with electrified vehicles have been underestimated for the final rule analysis. The agencies did refine the estimates for the value of refueling time for electric vehicles, and that topic is discussed in [Section Refueling Time]. The agencies will continue to explore whether and how charging infrastructure should be incorporated into the analysis for future actions.

The following sections discuss vehicle electrification issues that were accounted for in the analysis, including the agencies' characterizations of electric vehicle technology, additional electric vehicle configurations added for the final rule analysis per commenters' requests, and the sources and methods used to develop battery and non-battery components, which were also refined for this final rule.

a) Electrification Modeling in the CAFE Model

A set of technologies was chosen to represent the spectrum of electrification methods observed in the baseline fleet and that the agencies believed could be applied to vehicles in the rulemaking timeframe. Each technology was placed in a specific electrification pathway, grouping and defining the progression of related technologies. In the NPRM analysis, a total of eleven electrification technologies were contained in four electrification pathways. In consideration of comments received, the electrification technologies and associated pathways were modified for the final rule analysis, resulting in a total of eighteen variants of electrification technologies. Each of these NPRM and final rule technologies, and the electrification pathways they belong to, are detailed below. Operational modes of electrified vehicles are further described in the [FRM ANL model documentation].

(1) Electrification Technologies

(a) Electric Improvements

The electrification of power steering (EPS) and other accessories (IACC) have the potential of reducing fuel consumption by facilitating power-saving control strategies that avoid parasitic loss of engine power. These accessories traditionally are directly coupled to and driven by the conventional combustion engine; any time the engine is running some energy is continuously consumed by each accessory, even when it is not needed. By decoupling these accessories from the engine and instead driving them "on-demand" with electric motors, a more energy-efficient control strategy can be employed to reduce fuel consumption. EPS and IACC are discussed in detail in Section [ref Section on Other Technologies].

(b) Micro Hybrid

12-volt Stop-Start (SS12V), sometimes referred to as start-stop, idle-stop or 12-volt micro hybrid, is the most basic hybrid system that facilitates idle-stop capability. In this system, the integrated starter generator is coupled to the internal combustion (IC) engine. When the vehicle comes to an idle-stop the IC engine completely shuts off and, with the help of 12-volt battery, the engine cranks and starts again in response to throttle to move the vehicle, or release of the brake pedal. The 12-volt battery used for the start-stop system is an improved unit capable of higher power, increased life cycle, and capable of minimizing voltage drop on restart. This technology is beneficial to reduce fuel consumption and emissions when the vehicle frequently stops, such as in city driving conditions or in stop and go traffic, and can be applied to all vehicle technology classes.

(c) Mild Hybrids

The belt integrated starter generator (BISG) and crank integrated starter generator (CISG), sometimes referred to as mild hybrid systems, provide idle-stop capability and use a higher voltage battery with increased energy capacity over typical automotive batteries. The higher voltage allows the use of a smaller, more powerful and efficient electric motor/generator which replaces the standard alternator. In BISG systems, the motor/generator is coupled to the engine via belt (similar to a standard alternator), while the CISG integrates it to the crankshaft between the engine and transmission; both of these systems allow the engine to be automatically turned off as soon as the vehicle comes to a full stop. In addition, these motor/generators can recover braking energy while the vehicle slows down (regenerative braking) and in turn can propel the vehicle at the beginning of launch, allowing the engine to be restarted later. Some limited electric assist is also provided during acceleration to improve engine efficiency. The CISG system has a higher efficiency, but also higher cost than the BISG.

The agencies received limited high-level comments on CISG systems, with CARB stating that CISG systems are generally considered more capable and more efficient relative to BISG systems because they do not have the same belt-related constraints including maximum torque limitations, load restrictions on the front crank to avoid uneven crankshaft bearing wear, and mechanical energy transfer losses. CARB also noted that the decision to implement a CISG system is typically made early in the design process because doing so often requires an engine block casting change. CARB stated that the current high costs and larger dimensions, compared to BISGs, will likely delay major market penetration of CISG systems until beyond the MY 2025 timeframe.[863]

For the final rule analysis, the agencies did not include CISG systems. The effectiveness of CISG systems were similar to the BISG, and the high cost of the CISG caused it to be applied very seldomly. Other packaging and integration issues make it difficult for most vehicles to adopt CISG technology. Typically, a manufacturer would have to modify the flywheel housing to allow the installation of an electric motor, which must also fit where the system is mounted between the transmission and the engine block. Space in that part of the vehicle also comes at a

[863] NHTSA-2018-0067-11984.

premium because other components such as exhaust systems and piping systems must also be housed in the same area. In the final rule analysis, all vehicles previously considered to possess CISG technology were instead assigned a BISG system.

(d) Strong Hybrids

A hybrid vehicle is a vehicle that combines two or more sources of propulsion energy, where one uses a consumable fuel (like gasoline), and one is rechargeable (during operation, or by another energy source). Hybrids reduce fuel consumption through three major mechanisms, including (1) potential engine downsizing, (2) optimizing the performance of the engine to operate at the most efficient operating point and under some conditions storing excess energy such as by charging the battery, and (3) capturing energy during braking and some decelerations that might otherwise be lost to the braking system and using the stored energy to provide launch assist, coasting, and propulsion during stop and go traffic conditions. The effectiveness of the hybrid systems depends on how the above factors are balauced, taking into account complementary equipment and vehicle application. For some performance vehicles, the hybrid technologies are used for performauce improvement without any engine downsizing.

The NPRM analysis evaluated the following strong hybrid vehicles: hybrids with "P2" parallel drivetrain architecture (SHEVP2),[864] and hybrids with power-split architecture (SHEVPS). The parallel hybrid drivetrain, although enhanced by the electric portion, remains fundamentally similar to a conventional powertrain. In contrast, the power-split hybrid drivetrain is novel and considerably different than a conventional powertrain. Although these hybrid architectures are quite different, both types provide start-stop or idle-stop functionality, regenerative braking capability, and vehicle launch assist. A SHEVPS has a higher potential for fuel economy improvement than a SHEVP2, although its cost is also higher.

Power-split hybrid (SHEVPS) is a hybrid electric drive system that replaces the traditional transmission with a single planetary gear set (a/k/a the power-split device) and a motor/generator. This motor/generator uses the engine either to charge the battery or to supply additional power to the drive motor. A second, more powerful motor/generator is permanently connected to the vehicle's final drive and always turns with the wheels. The planetary gear splits engine power between the first motor/generator and the drive motor either to charge the battery or to supply power to the wheels. During vehicle launch, or when the battery state of charge (SOC) is high, the engine, which is not as efficient as the electric drive, is turned off aud the electric machine propels the vehicle. During uormal driving, the engine output is used both to propel the vehicle and to generate electricity. The electricity generated can be stored in the battery and/or used to drive the electric machine. During heavy acceleration, both the engine and electric machine (by consuming battery energy) work together to propel the vehicle. When braking, the electric machine acts as a generator to convert the kinetic energy of the vehicle into electricity to charge the battery.

[864] Depending on the location of electric machine (motor with or without inverter), the parallel hybrid technologies are classified as P0–motor located at the primary side of the engine, P1–motor located at the flywheel side of the engine, P2 – motor located between engine and transmission, P3–motor located at the transmission output, and P4–motor located on the axle.

The Autonomie simulations assumed all SHEVPS' used an Atkinson cycle engine (Eng-26). Therefore, all vehicles equipped with SHEVPS technology in the CAFE model simulations were assumed to have Atkinson cycle engines. This Atkinson cycle engine with high compression ratio is optimized for efficiency, rather than performance. Accordingly, SHEVPS technology as modeled in this analysis was not suitable for large vehicles that must handle high loads.[865] Further discussion of Atkinson engines and their capabilities is discussed in Section [Engines].

P2 parallel hybrids (SHEVP2) are a type of hybrid vehicle that uses a transmission-integrated electric motor placed between the engine and a gearbox or CVT, with a clutch that allows decoupling of the motor/transmission from the engine. Although similar to the configuration of the CISG system discussed previously, a P2 hybrid would typically be equipped with a larger electric machine and battery in comparison to the CISG. Disengaging the clutch allows all-electric operation and more efficient brake-energy recovery. Engaging the clutch allows efficient coupling of the engine and electric motor and, when combined with a transmission, reduces gear-train losses relative to power-split or 2-mode hybrid systems. P2 hybrid systems typically rely on the internal combustion engine to deliver high, sustained power levels. Only low and medium power demands are allowed for electric-only mode. Examples of SHEVP2's include the MY 2016 Hyundai Sonata Hybrid and MY 2016 Chevrolet Malibu Hybrid, among others.

In the NPRM CAFE modeling, the SHEVP2 system represented a hybrid system paired with an existing engine on a given vehicle, while the SHEVPS removed and replaced the previous engine with an Atkinson cycle engine. The agencies explained that while many vehicles may use HCR1 engines as part of a hybrid powertrain, HCR1 engines may not be suitable for all vehicles, especially high performance vehicles, or vehicles designed to carry or tow large loads [this is further discussed in the engine section]. Many manufacturers may prefer turbocharged engines (with high specific power output) for P2 hybrid systems, in order to maintain performance. Accordingly, in the NPRM analysis, to satisfy power demands, many SHEVP2 systems were paired with non-HCR powertrains.

~~EPA,~~ ICCT, and Mezler Engineering Services commented that as a result of NPRM CAFE Model constraints, low-cost, HCR engines were too infrequently paired with SHEVP2 technology. These commenters claimed that frequent pairing of SHEVP2 with downsized turbocharged engines resulted in higher cost and lower effectiveness for these strong hybrids.[866, 867, 868]

Commented [A254]: CHANGE AS SHOWN: As written, the inclusion of EPA in this statement implies this was a public comment; it was not, it was part of the interagency review docketed by EPA under the requirements of CAA 307(d). – or is this some other EPA?

[865] Kapadia, J., Kok, D., Jennings, M., Kuang, M. et al., "Powersplit or Parallel - Selecting the Right Hybrid Architecture," SAE Int. J. Alt. Power. 6(1):68-76, 2017, https://doi.org/10.4271/2017-01-1154.
[866] Reference EPA_comments_04-25-18 in EPA docket EPA-HQ-OAR-2018-0283 : http://our.dot.gov/office/nhtsa.nvs/NVS-100/NVS-130/NVS-132/Shared%20Documents/CAFE%20LD/2021-202X%20Rule/NPRM/Analysis/EOP/EPA_comments_04-25-18/Preliminary%20Comments%20of%20CAFE%20Model-%204_25_2018.pdf.
[867] Meszler Engineering Services, Attachment 2, Docket No. NHTSA-2018-0067-11723, at 15.
[868] International Council on Clean Transportation, Attachment 3, Docket No. NHTSA-2018-0067-11741, at 1-25.

In consideration of these comments, the final rule analysis includes additional strong hybrids (P2HCR0, P2HCR1, and P2HCR2[869]) which use HCR engines in a P2 parallel hybrid system. This provides another engine for P2 hybrid alternative. In contrast, the SHEVP2 technology allows the engine type to be inherited from the outgoing convention; this is unchanged from the NPRM and provides a good solution for vehicles which need to undergo hybridization but require other engine technologies (such as turbocharging) to meet performance requirements.

Commented [A255]: REVISE: Although the paraphrase of the comments in the previous paragraph males it sound like the main issue is the lack of HCR paired with hybrids, the main issue is that the expensive TDS engines are assumed to be inherited, when a non-TDS engine would be more cost-effective (because the effectiveness advantage of a TDS over a NA in a hybrid application is not near so great as in a non-hybrid application).

More specifically, the commenters are asking for a P2-GDI, not necessarily a P2-HCR. If the application of HCR is still restricted in the fleet, the inclusion of P2HCR will not have much uptake, and thus the response here isn't actually responsive.

(e) Plug-in Hybrids

Plug-in hybrid electric vehicles (PHEV) are hybrid electric vehicles with the means to charge their battery packs from an outside source of electricity (usually the electric grid). These vehicles have larger battery packs with more energy storage and a greater capability to be discharged than other non-plug-in hybrid electric vehicles. PHEVs also generally use a control system that allows the battery pack to be substantially depleted under electric-only or blended mechanical/electric operation and batteries that can be cycled in charge-sustaining operation at a lower state of charge than is typical of other hybrid electric vehicles. These vehicles generally have a greater all-electric range than the typical SHEVs discussed above. In the NPRM analysis, PHEVs with two all-electric ranges—a 30 mile and a 50 mile all-electric range (AER)—were included as potential technologies. The PHEV30 represented a "blended-type" plug-in hybrid, which can operate in all-electric (engine off) mode only at light loads and low speeds, and must blend electric machine and engine power together to propel the vehicle at medium or high loads and speeds. The PHEV50 represented an extended range electric vehicle (EREV), which is capable of travelling in all-electric mode even at higher speeds and loads.

Unlike other alternative fuel systems that require specific infrastructure for refueling or recharging (e.g., hydrogen vehicles or rapidly charged battery electric vehicles), PHEV batteries can be charged using existing infrastructure, although widespread adoption may require upgrades to electrical power distribution systems.[870] PHEVs are considerably more expensive than conventional vehicles and more expensive than SHEVPS technologies because of larger battery packs and charging systems capable of connecting to the electric grid.

Commenters, such as CARB, stated that in the NPRM analysis the PHEV motors were oversized and overpowered, and CARB stated PHEV30s result in excessive battery pack size and electric range when compared to actual production vehicles.[871] In response to such comments, the agencies, in collaboration with ANL, conducted further market analysis and determined that replacing PHEV30 (with a nominal 30 mile AER) with PHEV20 (with a nominal 20 mile AER) would more closely characterize the PHEVs actually in production [reference ANL ppt "NKim response on NPRM comments – 181112"]. The agencies therefore elected to replace PHEV30 with PHEV20 in the final rule.

[869] P2HCR2 was included in simulations used for sensitivity studies, but was excluded in the central analysis simulations for reasons surrounding the HCR2 engine, as discussed in the [ref engine section].
[870] See below for a discussion of electrical vehicle infrastructure.
[871] California Air Resources Board, Attachment 2, Docket No. NHTSA-2018-0067-11873, at 150,153.

The final rule also includes four additional types of plug-in hybrids; two additional plug-in hybrids were added to allow the use of turbocharged engines (PHEV20T, PHEV50T), and two additional plug-in hybrids were added to provide maximum efficiency by utilizing an Atkinson cycle engines (PHEV20H, PHEV50H).

In practice, many PHEVs recently introduced in the marketplace use turbo-charged engines in the PHEV system, and this is particularly true for PHEVs produced by European manufacturers and for other PHEV performance vehicle applications. However, the Autonomie simulations (and thus all the CAFE model simulations) assumed all PHEVs use a naturally aspirated, Atkinson cycle engine. The agencies determined through continued marketplace observation that PHEV vehicles should indeed be allowed to adopt or retain turbocharged engines. Also, BorgWarner commented that modeling of PHEVs should include turbocharged engines, since these engines can be downsized to reduce vehicle mass and fit into smaller engine compartments, and offer efficiency and performance advantages especially when paired with a higher expansion ratio.[872] Thus, in addition to the PHEV20 and PHEV30, the final rule analysis included PHEV20T and PHEV50T variations which are, respectively, 20 and 50 mile all electric range PHEV's with turbocharged engines.

This final rule also added PHEV20H and PHEV50H, although effectively these are not used by the model simulations. These plug-in types represent 20 and 50 mile all electric range plug-in hybrids that use particularly efficient high-compression, Atkinson cycle engines. These were added with the intent to provide PHEVs with a maximum level of fuel economy at a lower cost. However, they proved to be too similar to existing plug-in technology choices and were thus assigned identical characteristics as the PHEV20 and PHEV50. Effectively then, the PHEV20H and PHEV50H technologies are still considered by the CAFE model but they remain as "placeholders" for potential incorporation in future analyses.

Commented [A256]: **REVISE:** This sounds like "Atkinson engines perform no better in a (P2) hybrid application than non-Atkinson NA engines, but are more expensive" which suggests that non-Atkinson NA engines should be included in the non-plug-in version of the P2, which was the point of the commenters a page ago in the prior comment bubble.

(f) Battery Electric Vehicles

Electric vehicles (EVs), or battery electric vehicles (BEVs) are equipped with all-electric drive and with systems powered by energy-optimized batteries charged primarily from grid electricity. The range of a battery electric vehicle depends on the vehicle's class and the battery pack size. The NPRM analysis included BEVs with a range of 200 miles.

Following the NPRM, the agencies conducted continued market analysis of production BEV's, and observed a growing number of vehicles with nominal ranges above 200 miles. CARB also commented that certain BEVs modeled as BEV200 in the NPRM in fact had "well over 200 miles of range."[873] The agencies thus concluded that a 300-mile-range BEV300 should be included in the final rule to represent better these higher-range electric vehicles as well as a potential future range alternative more comparable to IC engines. The agencies still believe that, in the rulemaking timeframe, BEV300 will be the most cost effective extended range BEVs that could be available for adoption. Longer-range electric vehicles could have been modeled in the analysis, but the compliance simulation would likely not have selected the longer-range vehicle

[872] BorgWarner, Attachment 2, Docket No. NHTSA-2018-0067-11873, at 150,153.
[873] California Air Resources Board, Attachment 2, Docket No. NHTSA-2018-0067-11873, at 147.

if lower-range vehicles were still available. This is because the CAFE model only applies technologies until a manufacturer meets its CAFE or CO_2 standard, and the BEV200 and BEV300 vehicles operate functionally the same in helping a manufacturer towards meeting its compliance obligations. The only difference between these vehicles is cost. As discussed further in [BEV Adoption Features] below, the agencies used phase-in caps to control expected BEV200 and BEV300 penetration based on the current trend and future assumption that consumers will transition towards longer-range electric vehicles.

(g) Fuel Cell Vehicles

Fuel cell electric vehicles (FCEVs or FCVs) utilize a full electric drive platform but consume hydrogen fuel to generate electricity in an onboard fuel cell. Fuel cells are electrochemical devices that directly convert reactants (hydrogen and oxygen via air) into electricity, with the potential of achieving more than twice the efficiency of conventional internal combustion engines. High pressure gaseous hydrogen storage tanks are used by most automakers for FCEVs. These high pressure tanks are similar to those used for compressed gas storage in more than 10 million CNG vehicles worldwide, except that they are designed to operate at a higher pressure (350 bar or 700 bar vs. 250 bar for CNG), and to contain the very small, and very flammable, gaseous hydrogen molecule. FCEVs are currently produced in limited numbers and are available in limited geographic areas.

(2) Electrification Pathways

The electrification technologies described above were applied in the CAFE model through a number of technological pathways. Three main electrification technology pathways were modeled: the Electric Improvements Path, the Electrification Path, and the Hybrid/Electric Path. These three electrification pathways are evaluated in parallel by the CAFE model; the model can consider any of the three right away, and does not need to go "through" one pathway in order to begin evaluating another one. Any superseded technology is also disabled whenever a succeeding technology is applied to a vehicle, even if a specific superseded technology was not previously utilized on that vehicle. As previously explained, this requirement exists so that the modeling system does not downgrade technologies during analysis.

The Electrics Improvements Path defined in the NPRM and final rule is shown in Figure VI-21Figure VI-21 below, which starts with EPS and progresses to IACC. While these two electrified-accessory technologies are mutually exclusive, either one can be modularly paired with any other technology, including those in the other electrification pathways.

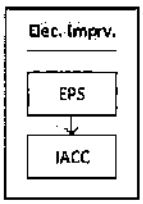

Figure VI-21 - NPRM and FRM Electrics Improvement Path

The Electrification Path shown in Figure VI-22Figure VI-22 allows a conventional powertrain to become a micro-hybrid with SS12V, or a mild-hybrid with BISG, or CISG (which is no longer available for the final rule analysis, as discussed previously) technologies. All three of the Electrification Path technologies are mutually exclusive with respect to all conventional powertrain technologies, as well as technologies contained in the Hybrid/Electric path discussed below. The model first evaluates SS12V, and then progresses to BISG or CISG (NPRM-only). The conventional engine technology CONV is grayed out to indicate that the model uses information about the previous conventional (non-electrified) powertrain to map properly to simulation results found in the vehicle simulation database. Although the adoption of these technologies will classify a vehicle as a micro/mild hybrid (MHEV) and no longer a conventional (CONV), the vehicle is allowed to retain the engine and transmission technologies possessed before entering the Electrification Path.

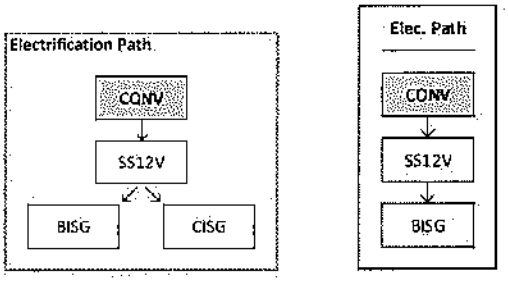

Figure VI-22 - NPRM (left) and Final Rule (right) Electrification Pathways

The Hybrid/Electric Pathways are shown in Figure VI-23Figure VI-23**Error! Reference source not found.**. Both the NPRM and final rule Hybrid/Electric paths begin at the "strong hybrid" technology types, each of which is mutually exclusive of the others; once one is chosen, the other is eliminated from future selection for that vehicle. The paths then progress into plug-in hybrids and then culminate with the mutually exclusive battery electric vehicles or fuel cell vehicles. The additional final rule technologies described above can be found in the final rule Hybrid/Electric pathway on the right side of Figure VI-23Figure VI-23**Error! Reference source not found.**, in comparison to the NPRM technologies shown on the left side of the figure.[874] The hybrid/electric pathways contains multiple "roots," or starting points, which force a vehicle to remain within the branches of a chosen root. For example, the final rule hybrid/electric pathway has three roots: SHEVP2, SHEVPS, and P2HCR0. If a vehicle uses SHEVPS, then SHEVP2 technology and the entire P2HCR0 through PHEV50H branch will be disabled from further consideration. In other words, from one technology in the pathway, a vehicle can only move forward along any of the indicated arrows, and never in the reverse direction. Also, when using

[874] Note that the NPRM Hybrid/Electric Path (left side of **Error! Reference source not found.**) refers to a portion of the path containing plug-in hybrids and electric vehicles as the "Advanced Hybrid/Electric Path." For this discussion, we will simply refer to the entire collection of these technologies, including the "Advanced" ones, as the "Hybrid/Electric Path."

any technology in the Hybrid/Electric pathway, with the exception of SHEVP2, all engine and transmission technologies as well as the Electrification Path technologies shown in Figure VI-23Figure VI-23 are prohibited. SHEVP2 is an exception because it allows engine technologies previously held by the vehicle to be inherited into the parallel hybrid system.

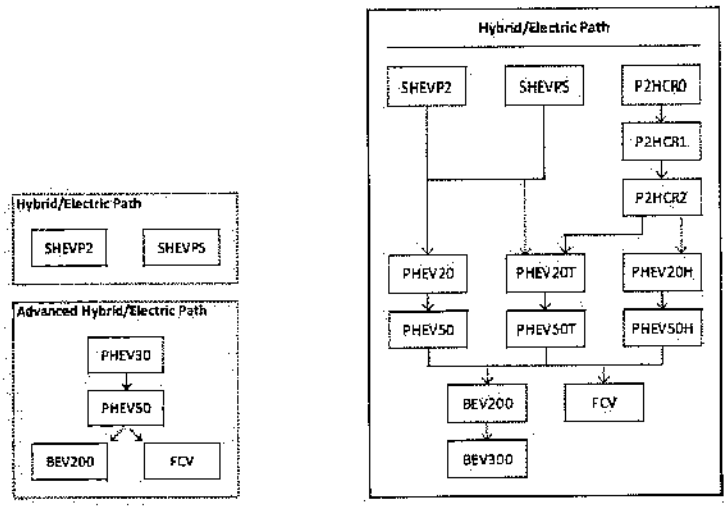

Figure VI-23 - NPRM (left) and Final Rule (right) Hybrid/Electric Pathways

b) Electrification Analysis Fleet Assignments

[Text Forthcoming]

c) Electrification Adoption Features

In the NPRM and final rule analysis, electrification adoption features were applied in multiple ways. First, when an electrification technology is selected, a path logic is applied that dictates what other technologies are either superseded or mutually exclusive to the applied technology. For a detailed discussion of path logic for the final rule analysis, including technology supersession logic and technology mutual exclusivity logic, please see [CAFE model documentation S4.5]. Second, application of the more advanced electrification technologies, such as the strong hybrids, plug-in hybrids, and full electric, result in major changes to the whole powertrain. The changes to the powertrain include substitution of transmission and engine technologies, and accordingly these technologies can only be applied at a vehicle redesign, as shown in Table VI-57Table VI-57 below. Finally, some of electrificatiou technologies are restricted from application to certain vehicle classifications. These restrictions will be discussed under the specific technology sections.

The fully-electric technologies, BEV technology and FCV technology, qualify as alternative fuel technologies. As a result, these technologies are not considered during portions of the agencies' analysis. Specifically, the exclusion of alternative fuel technology from NHTSA's analysis of potential fuel economy standards is a result of statutory obligations prescribed under EPCA/EISA.[875] However, NHTSA performed two fuel economy analyses, a standard-setting analysis that constrained the use of the technologies, and an unconstrained analysis that did not exclude the technologies, which provides an estimation of real-world environmental impacts used as inputs for the Environmental Impact Statement (EIS). The unconstrained analysis included the alternative fuel technologies, and used the adoption features for BEVs and FCVs discussed below. Further, for purposes of analyzing EPA's tailpipe CO_2 emissions rulemaking pursuant to the Clean Air Act, consideration of these technologies is likewise unconstrained. For a detailed discussion of the analysis versions and statutory obligations please refer to [Discussion of model runs X].

The exclusion of the BEV and FCV technology from the standard-setting analysis resulted in a comment from ICCT. ICCT stated, "the agencies prevented their fleet compliance model from allowing battery electric vehicles from being applied in their analysis of the Augural standards."[876] The agencies believe this reflects a misunderstanding of NHTSA's statutory obligation under EPCA/EISA and how the agencies ran the analysis. NHTSA did consider alternative fueled vehicles in the unconstrained analysis—but is prohibited from considering the availability of such technologies when setting maximum feasible standards.

[875] 49 U.S.C. 32902(b)(1). A "dedicated automobile" is defined in 49 U.S.C. 32901 as "an automobile that only operates on alternative fuel."
[876] Comments from ICCT, Attachment 3, Appendix, NPRM Docket No. NHTSA-2018-0067-11741, at 182.

Table VI-57 - CAFE Model Electric Technologies

Technology	Application Level	Application Schedule	Description
EPS	Vehicle	Refresh/Redesign	Electric Power Steering
IACC	Vehicle	Refresh/Redesign	Improved Accessories
SS12V	Vehicle	Redesign Only	12V Micro-Hybrid (Stop-Start)
BISG	Vehicle	Redesign Only	Belt Mounted Integrated Starter/Generator
SHEVP2	Vehicle	Redesign Only	P2 Strong Hybrid/Electric Vehicle
SHEVPS	Vehicle	Redesign Only	Power Split Strong Hybrid/Electric Vehicle
P2HCR0	Vehicle	Redesign Only	[Special] SHEVP2 with HCR0 Engine
P2HCR1	Vehicle	Redesign Only	[Special] SHEVP2 with HCR1 Engine
P2HCR2	Vehicle	Redesign Only	[Special] SHEVP2 with HCR2 Engine
PHEV20	Vehicle	Redesign Only	20-mile Plug-In Hybrid/Electric Vehicle with HCR Engine
PHEV50	Vehicle	Redesign Only	50-mile Plug-In Hybrid/Electric Vehicle with HCR Engine
PHEV20T	Vehicle	Redesign Only	20-mile Plug-In Hybrid/Electric Vehicle with Turbo Engine
PHEV50T	Vehicle	Redesign Only	50-mile Plug-In Hybrid/Electric Vehicle with Turbo Engine
PHEV20H	Vehicle	Redesign Only	[Special] PHEV20 with HCR Engine
PHEV50H	Vehicle	Redesign Only	[Special] PHEV50 with HCR Engine
BEV200	Vehicle	Redesign Only	200-mile Electric Vehicle
BEV300	Vehicle	Redesign Only	300-mile Electric Vehicle
FCV	Vehicle	Redesign Only	Fuel Cell Vehicle

(1) Start Stop12V and Belt-Integrated Starter Generator Systems

For the NPRM and final rule analysis, the only adoption features for the SS12V and BISG technologies were functions of path logic. The SS12V and BISG technologies were allowed for consideration in any existing vehicle configuration that did not already have a more advanced electrification technology applied. Per Table VI-57Table VI-57 above, the BISG technology was considered more advanced than the SS12V technology.

EDF commented that 48V batteries used in conjunction with 12 volt systems (what are referred to in the analysis as BISG systems) are one example of a "bolt-on" technology that can be added to a vehicle during a product refresh without causing production problems or significantly increasing costs.[877] EDF stated that 48V systems do not require reengineering of the engine and can be added at any time during a model's lifespan, as shown by key suppliers that are expanding production capacity to meet customer demand for the technology.[878] EDF also pointed to examples of vehicles that utilize 48V systems, including high-volume non-luxury vehicles like the Ram pickup truck, Jeep Wrangler, and Ford F-150.[879]

The agencies disagree with EDF's assessment of 48V technology as a "bolt-on" technology. Although BISG systems represent a first step in vehicle electrification, and the number of components involved is fewer than most other types of hybrid systems, a BISG system still requires engineering and packaging of motors, cooling systems, additional wiring harnesses from the 48V battery pack to the motors, control systems, and other components incorporated into the front engine compartment. Further, the addition of a BISG system requires recalibration and validation of numerous engine performance parameters, including emissions controls, balancing torque supply to the transmission between the BISG system and engine, and noise-vibration-harshness controls. In additional, the examples EDF provided support the agencies' designation of SS12V and BISG systems as redesign technologies; the BISG system in the MY 2019 Ram pickup and in the MY 2018 Jeep Wrangler were introduced during a product redesign and not during a mid-cycle product refresh.[880, 881] Although Ford has indicated that the F-150 will include hybrid variants,[882] the agencies do not have information about specific plans for a 48V system on the F-150. In consideration of this information, the agencies maintained the redesign schedule for mild hybrids for the final rule analysis.

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[877] NHTSA-2018-0067-10653 (citing A.K. Kumawat and A.K. Thakur, *A Comprehensive Study of Automotive 48V Technology*, SSRG International Journal of Mechanical Engineering (SSRG - IJME), Vol. 4 (5) (May 2017), available at: https://jalopnik.com/everything-you-need-to-know-about-the-upcoming-48-volt-1790364465 (last viewed 10/23/2018)).

[878] NHTSA-2018-0067-10653.

[879] NHTSA-2018-0067-10653.

[880] *See*, e.g., K.C. Colwell, *The 2019 Ram 1500 eTorque Brings Some Hybrid Tech, If Little Performance Gain, to Pickups*, Car and Driver (Mar. 14, 2019), available at: https://www.caranddriver.com/reviews/a22815325/2019-ram-1500-etorque-hybrid-pickup-drive/ ("Any 2019 Ram 1500—the all-new one, not the Ram Classic that is just a continuation of the previous generation—can be equipped with a motor/generator attached to its engine's crankshaft via a belt that is capable of adding torque, cranking the engine in a stop/start event, or making electricity with regenerative braking.").

[881] *See*, e.g., Tony Quiroga, *The 2018 Jeep Wrangler Hybrid Provides Effortless Thrust, Much Improved Fuel Economy*, Car and Driver (Oct. 15, 2018), available at: https://www.caranddriver.com/reviews/a23746585/2018-jeep-wrangler-unlimited-suv-turbo-four-cylinder-hybrid/ ("Completely redesigned for 2018, the Wrangler is even more like a Power Wheels now that it's available with an electric motor.").

[882] [citation forthcoming].

(2) Strong Hybrids – SHEVP2, SHEVPS, P2HCR0, P2HCR1, P2HCR2

For the NPRM analysis the Strong Hybrid technologies included path logic, powertrain substitution and vehicle class restriction adoption features. For the NPRM analysis technologies on the Hybrid/Electric path (SHEVP2 and SHEVPS) are defined as stand-alone and mutually exclusive. When the modeling system applies one of those technologies, the other one is immediately disabled from future application. Once a strong hybrid technology is applied it also supersedes lower technologies on the electrification path, allowing future application of technology to consider only more advanced forms of electrification.

In the NPRM when the SHEVP2 technology or the SHEVPS technology were applied, the transmission technology was superseded. Regardless of the transmission technology present when the technology is applied, the transmission technology was replaced by either the AT6 or DCT6. The specific transmission technology selected was based on choosing the best cost versus effectiveness.

During the NPRM analysis when the SHEVP2 technology was selected the engine technology for the platform was maintained. However, the engine technology was locked at the current level and could not be changed. For the SHEVPS technology the existing engine was replaced with an Atkinson cycle engine (Eng-26).

The SHEVPS also had constraints on vehicle class application in the NPRM. Application of the power-split powertrain architecture was restricted from high performance vehicles and vehicles with a required high towing capability.[883] This restriction was accomplished using a vehicle technology class filter, restricting application from the pick-up and performance pick-up class of vehicles, as well as limiting application from any platform with a base horse power rating greater than 400 HP. Additional platforms were also restricted based on an engineering analysis of the platforms' initial design and intended use.

Comments from ICCT criticized the manner in which SHEVP2 technology was applied to a platform. ICCT states "the benefits of level-2 transmission efficiency and TURBO2 over TURBO1 are removed when P2 strong hybrid systems (SHEVP2) are selected on the electrification pathway."[884]

Additional comments regarding the adoption features of the SHEVP2 technology were received from Meszler Engineering and ICCT. Meszler argued that the locking of engine technologies when a manufacturer selects the SHEVP2 technology may preclude the selection of a more cost-effective engine technology.[885] This concern was echoed by ICCT, who also felt the engine technology lock-in artificially increased cost for effectiveness on the overall SHEVP2

[883] Power split or Parallel–selecting the Right Hybrid Architecture: SAE 2017-01-1154.
[884] Comments from ICCT, Attachment 3, Appendix [Insert info], NPRM Docket No. NHTSA-2018-0067-11741, at I25.
[885] Comments from Meszler Engineering Services, Attachment 2, NPRM Docket No. NHTSA-2018-0067-11723, at 15-16.

technology packages.[886] Both commenters specifically wanted an option for a high compression ratio engine technology to be considered in place of any advanced engine technology carried into the SHEVP2 technology pathway.

The agencies agreed with the need for maintaining the benefits of a higher transmission technology, and for the final rule analysis a AT8L2 transmission technology replaced the AT6 or DCT6 transmissions for all hybrid-electric technologies. The AT8L2 was selected as the optimal transmission technology point for HEV systems. The transmission technology point was selected based on observed diminishing returns for applying advanced transmission technologies to advanced engine/powertrains.[887]

The agencies also reconsidered engine options for SHEVP2 technology, and other strong hybrid-electric technologies. The agencies agreed with Meszler and ICCT's observation and instituted new P2 engine technology options, as discussed above. For the final rule analysis, when a platform considered the SHEVP2 option, the platform also compared maintaining the current engine technology, or selecting an HCR technology. If the SHEVP2 system chooses to apply a HCR engine, the system diverts to the new electrification sub-path of technologies including the P2HCR0, P2HCR1, and P2HCR2.

The P2HCR path introduced in the final rule analysis had similar constraints as the SHEVPS. Performance vehicles and vehicles with a high towing requirement were restricted from selection of the P2HCR technology. Restrictions that were applied used the same criteria described for the SHEVPS.

(3) Plug-in Hybrids - PHEV20/30, PHEV50, PHEV20T, PHEV50T, PHEV20H, PHEV50H

The plug-in hybrid options in the NPRM included PHEV30 and PHEV50 technologies. The plug-in technologies superseded the micro, mild, and strong hybrid electrification technologies and could only be replaced by full electric technologies. The path logic also allowed a PHEV30 to progress to a PHEV50.

In the NPRM, when a platform progressed to the plug-in hybrid technologies the powertrain was automatically modified. The engine technology was replaced by a high compression ratio engine (Eng-26) and the transmission was replaced by the AT6 or DCT6 technology.

PHEV30 and PHEV50 were also constrained from application to vehicles with the potential for high towing demands.[888] This constraint was applied by restricting access to the

[886] Comments from ICCT, Attachment 3, Appendix [Insert info], NPRM Docket No. NHTSA-2018-0067-11741, at 125-126.
[887] 2015 NAS Report - The National Academy of Science, in their 2015 report, noted that "as engines incorporate new technologies to improve fuel consumption, the benefits of increasing transmission ratios or switching to a CVT diminish."
[888] [Text Forthcoming].

pickup truck vehicle technology class. Additional specific vehicle platforms were restricted based on engineering judgment.

Comments were received regarding the options for PHEV battery-electric technology. The comments are presented and discussed in [Paragraph i.d.] above, and resulted in the creation of additional technology options for plug-in hybrids, as well as a modification of available ranges. Comments were also received regarding the engine and transmission options used in the electrification technologies, these comments are also presented and discussed above in [Paragraph X].

For the final rule analysis, the plug-in hybrid options included PHEV20, PHEV50, PHEV20T, PHEV50T, PHEV20H, and PHEV50H. As with the NPRM, the plug-in technologies superseded the micro, mild, and strong hybrid technologies. For the final rule analysis, plug-in hybrid technologies were also mutually exclusive, and the PHEV20 technologies can progress to the PHEV50 technologies.

When a platform applied plug-in hybrid technologies in the final rule analysis, the engine and transmission technologies are superseded. For all plug-in technologies, an AT8L2 transmission is used. For the PHEV20/50 and PHEV20/50H, the engine is replaced by an Atkinson cycle based engine (Eng 26). For the PHEV20/50T, the engine is replaced by the TURBO1 technology engine (Eng-12).

The PHEV20/30 and PHEV20/50H path also had similar constraints as the SHEVPS in the final rule analysis. Performance vehicles and vehicles with a high towing requirement were restricted from selection of the PHEV20/30 and PHEV20/50H technologies. Restrictions that were applied used the same criteria described for the SHEVPS.

(4) Battery Electric Vehicles

For the NPRM analysis, the BEV200 technology was applied as an end-of-path technology. The BEV200 technology was the only battery electric vehicle option.

For the final rule analysis, the BEV300 was added as a technology option beyond the BEV200, as discussed in [Paragraph above]. The BEV technology was applied in place of all engine and transmission technologies, and was an end of path technology.

For the final analysis, both the BEV 200 and BEV300 had phase-in cap limitations applied based on an analysis of the market availability and cost of batteries.[889] The BEV200 was limited to a greater extent than the BEV300, accounting for expected limits in market demand for the shorter-range BEV.[890] The values for the phase-in capacity numbers were determined based on the results of the analysis of the National Energy Model System (NEMS) discussed in [Paragraph X].

[889] [https://www.digitaltrends.com/cars/mit-study-finds-ev-market-will-stall-in-the-2020s/].
[890] [http://energy.mit.edu/research/mobilityofthefuture/].

(5) Fuel Cell Vehicle

For the NPRM analysis, FCV technology was also applied as an end of path technology. The FCV technology was also applied as end of path technology in the final rule analysis.

For the final rule analysis, a phase-in cap was assigned to FCV technology. The phase-in cap was assigned based on existing market share as well as an analysis of expected infrastructure availability during the time frame of regulation.[891, 892]

d) Electrification Effectiveness Modeling and Resulting Effectiveness Values

[Text Forthcoming]

e) Electrification Costs

[Text Forthcoming]

4. Mass Reduction

Mass Reduction is a relatively cost-effective means of improving fuel economy and reducing CO_2 emissions, and is one of the key methods by which vehicle manufacturers are expected to apply to meet fuel economy and CO_2 standards. Reducing vehicle mass can be accomplished through several different techniques, such as modifying and optimizing vehicle component and system designs, part consolidation, and adopting lighter weight materials (advanced high strength steel, aluminum, magnesium, and plastics including carbon fiber reinforced plastics). The cost for mass reduction depends on the type and amount of materials used, the manufacturing and assembly processes required, and the degree to which changes to plants and new manufacturing and assembly equipment is needed. In addition, manufacturers may develop expertise and invest in certain mass reduction strategies that may affect the approaches for mass reduction they consider and the associated costs. Manufacturers may also consider vehicle attributes like noise-vibration-harshness (NVH), ride quality, handling, and various acceleration metrics when considering how to implement any mass reduction strategy (see Section [maintaining vehicle attributes] for more details).

The automotive industry uses different metrics to measure vehicle weight. Some commonly used measurements are vehicle curb weight,[893] gross vehicle weight (GVW),[894] gross

[891] [Trends report–market share of Fuel Cell technology].
[892] [http://energy.mit.edu/research/mobilityofthefuture/].
[893] This is the weight of the vehicle with all fluids and components but without the drivers, passengers, and cargo.
[894] This weight includes all cargo, extra added equipment, and passengers aboard.

vehicle weight rating (GVWR),[895] gross combined weight (GCVW),[896] and equivalent test weight (ETW),[897] among others.

The vehicle curb weight is the most commonly used measurement when comparing vehicles. A vehicle's curb weight is the weight of the vehicle including fluids, but without a driver, passengers, and cargo. It is important to compare curb weight in the same vehicle class to understand if one particular vehicle make and model is lighter than the others.

A vehicle's glider weight, which is vehicle curb weight minus the powertrain weight, is used to track the potential opportunities for weight reduction not including the powertrain. A glider's subsystems may consist of the vehicle body, chassis, interior, steering, electrical accessory, brake, and wheels systems. However, as noted in the PRIA, the definition of a glider may vary from study to study (or even simulation to simulation).

Each of the subsystems presents an opportunity for weight reduction; however, some weight reduction is dependent on the weight reduction of other subsystems. The agencies characterize mass reduction as either primary mass reduction or secondary mass reduction. Primary mass reduction involves reducing mass of components that can occur independent from the mass of other components. For example, the mass of a hood (e.g., replacing a steel hood with an aluminum hood) or reducing the mass of a seat are examples of primary mass reduction because each can be implemented independently. Other components and systems that may contribute to primary mass reduction include the vehicle body, chassis, and interior components.

When significant primary mass reduction occurs, other components designed based on the mass of primary components may be redesigned as well. An example of a subsystem where secondary mass reduction can be applied is the brake system. If the mass of primary components is reduced sufficiently, the resulting lighter weight vehicle could safely maintain braking performance and attributes with a lighter weight brake system. Other examples of components where secondary mass reduction can be applied are wheels and tires.

For this analysis, the agencies consider mass reduction opportunities from the glider subsystems of a vehicle first, and then consider associated opportunities to downsize the powertrain, which are accounted for separately.[898] As explained later, in the Autonomie simulations, the glider system includes both primary and secondary systems from which a percentage of mass is reduced for different glider weight reduction levels; specifically, the glider includes the body, chassis, interior, electrical accessories, steering, brakes and wheels. The

[895] This is the maximum total weight of the vehicle, passengers, and cargo to avoid damaging the vehicle or compromising safety.
[896] This weight includes the vehicle and a trailer attached to the vehicle, if used.
[897] For the EPA 2 cycle regulatory test on a dynamometer, additional weight of 300 lbs. is added to the vehicle curb weight. This additional 300 lbs. represents the weight of driver, passenger, and luggage. Depending on the final test weight of the vehicle (vehicle curb weight plus 300 lbs.), a test weight category is identified using the table published by EPA according to 40 CFR § 1066.805. This test weight category is called "Equivalent Test Weight" (ETW).
[898] When the mass of the vehicle is reduced by an appropriate amount, the engine may be downsized to maintain performance. See Section [maintaining vehicle attributes] and Section [performance neutrality] for more details.

model sizes the powertrain based on the glider weight and the mass of some of the powertrain components in an iterative process. The mass of the powertrain depends on the powertrain size. Therefore, the weight of the glider impacts the weight of the powertrain.[899] See Section [How we build vehicle models for Autonomie] and Section [How Autonomie Sizes Powertrains for Full Vehicle Simulation] for more details.

The agencies use glider weight to apply non-powertrain mass reduction technology, and use Autonomie simulations to determine the size of the powertrain and corresponding powertrain weight for the respective glider weight. The combination of glider weight (after mass reduction) and re-sized powertrain weight equal the vehicle curb weight. See Section [glider mass and mass reduction subsection below] for more detail on glider mass and glider mass reduction.

a) Mass Reduction in the CAFE Model

Several studies have explored the amount of vehicle mass reduction that is feasible in the rulemaking timeframe and the cost for that mass reduction.[900,901,902,903] Those studies were spousored by the agencies, CARB, ICCT, the automotive industry, and material manufacturers, and are discussed in Section VI.C.4.e)(1), below. All of the studies showed that the maximum feasible amount of mass reduction that can be applied in the rulemaking timeframe is around 20 percent of a baseline vehicle's curb weight. The National Academies of Sciences similarly concluded, based on some of these same studies along with other information, that it is feasible to reduce up to 20 percent of the mass of the vehicle.[904]

As discussed in Section VI.C.4.e), the mass reduction studies show that the cost for mass reduction increases progressively as the amount of mass reduction increases. In other words, lower levels of mass reduction are more cost effective than higher levels of mass reduction. As in past rulemakings, the agencies have considered multiple levels of mass reduction to provide options similar to what manufacturers could consider at vehicle redesigns.

For the NPRM, the agencies included five levels of mass reduction with a maximum of 20 percent glider mass reduction, corresponding to 10 percent curb mass reduction, using the assumption that the glider was 50 percent of curb weight.

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[899] Since powertrains are sized based on the glider weight for the analysis, glider weight reduction beyond a threshold amount during a redesignwill lead to re-sizing of the powertrain. For the analysis, the glider was used as a base for the application of any type of powertrain. A conventional powertrain consists of an engine, transmission, exhaust system, fuel tank, radiator and associated components. A hybrid powertrain also includes a battery pack, electric motor(s), generator, high voltage wiring harness, high voltage connectors, inverter, battery management system(s), battery pack thermal system, and electric motor thermal system.

[900] DOT HS 811 692; Investigation of Opportunities for Lightweight Vehicles Using Advanced Plastics and Composites

[901] A Review of the Safety of Reduced Weight Passenger Cars and Light Duty Trucks by Michigan Manufacturing Technology Center, October 2018

[902] ATG Silverado Body Light weighting Study, Aluminum Technology Group, January 2017

[903] 2013 NanoSteel Intensive Body-In-White, EDAG and NanoSteel Company Inc

[904] [Text Forthcoming].

Table VI-58 - NPRM Mass Reduction Technology Level and Associated Glider and Curb Mass Reduction (Passenger Cars and Light Trucks)

MR Level	MR % (50% Glider Share)	Approximate Percentage Mass Reduction at Curb Weight Level
MR0	0%	0.0%
MR1	5%	2.5%
MR2	7.5%	3.8%
MR3	10%	5.0%
MR4	15%	7.5%
MR5	20%	10.0%

The agencies received a number of comments suggesting that the amount of mass reduction allowed should be 20 percent of curb weight, as well as the assumption that glider share represents 75 percent of curb weight. These comments are addressed in more detail in [MR Technology Effectiveness Section] below, but some understanding of how the glider share assumption affects the maximum amount of mass reduction allowed in the CAFE Model is required here.

Several commenters stated that the agencies should allow further levels of mass reduction technology improvements in the CAFE model. For example, ICCT commented that the agencies must revise their treatment of mass reduction, because studies have demonstrated that at least 20% mass reduction of curb weight is available for adoption across vehicle classes by 2025.[905] ICCT stated that based on these studies, the agencies must increase the maximum available mass reduction potential levels to include up to 20% and 25% mass reduction of curb weight, as the industry "will cost-effectively deploy at least 15% vehicle curb mass reduction in the 2025 timeframe at net zero cost." ICCT caveated that amount of mass reduction seems less likely in smaller cars, which typically employ lower levels of mass reduction, so a constraint of 7.5 percent mass reduction as was applied in the Draft TAR would be appropriate for those vehicles.

ICCT also commented that there were numerous material improvements in development that were not considered in the rule, including but not limited to higher strength aluminum, improved joining techniques for mixed materials, third-generation steels with higher strength and enhanced ductility, a new generation of ultra-high strength steel cast components, and metal/plastic hybrid compoonents, among other technologies mentioned in ICCT's working paper on light-weighting.[906]

In assessing these comments, the agencies reconsidered the mass reduction studies and available reports and agree that greater that 10 percent mass reduction should be available for the

[905] ICCT also alleged that the agencies intentionally disregarded the studies that presented this result; those comments are discussed in [Mass Reduction Costs Section], below.
[906] NHTSA-2018-0067-11741.

final rule analysis. In response to comments, the agencies made two adjustments to allow higher levels. First, as explained in Section [glider mass and mass reduction], below, the agencies increased the glider percentage of vehicle curb weight used for the analysis from 50 percent to 71 percent. As explained in that section, increasing the glider percentage also increases the amount of curb weight reduction for all levels of mass reduction. Second, the agencies created another level of mass reduction (MR6) in the CAFE model, which represents a significant application of carbon fiber in the vehicle to achieve nearly 30 percent reduction in glider weight (which approximately translates to 20 percent reduction in vehicle curb weight. For example, by incorporating a carbon fiber tub,[907] or a carbon fiber monocoque with aluminum sub frame in the front and back,[908] or a carbon fiber splitter and carbon fiber wheels,[909] allows for greater level of mass reduction, albeit, at a very high cost. These technologies are not ready for high volume production vehicles.

Table VI-59Table VI-59 shows the levels of mass reduction technology available for application in the final rule analysis, with the associated glider weight percentage reduction and the percentage curb weight reductions for passenger cars and light trucks. As discussed in [MR Adoption Features section] below, the agencies declined to place a constraint on the amount of mass reduction technology that smaller cars could adopt.

Table VI-59 - Final Rule Mass Reduction Technology Level and Associated Glider and Curb Mass Reduction

MR Level	Percent Glider Weight	Percent Vehicle Curb Weight (Passenger Cars)	Percent Vehicle Curb Weight (Light Trucks)
MR0	0%	0.00%	0.00%
MR1	5%	3.55%	3.55%
MR2	7.5%	5.33%	5.33%
MR3	10%	7.10%	7.10%
MR4	15%	10.65%	10.65%
MR5	20%	14.20%	14.20%
MR6	28%	20.00%	20.00%

The agencies continue to believe the maximum feasible mass reduction levels identified in comprehensive design studies, such as those discussed in Section I.E., are the most reliable for projecting the maximum amount of mass reduction in the rulemaking timeframe, and therefore have determined MR6 is the highest level that should be used for the final rule analysis. While the information provided by ICCT on newer materials and manufacturing and assembly

[907] The BMW i3 and BMW i8, which are about 20 percent lighter than an average MY 2017 vehicle, use a carbon fiber tub

[908] The Alfa Romeo 4c/4c Spider, which is about 20 percent lighter than an average MY 2017 vehicle, uses this design

[909] The Ford Shelby GT350R which is about 20 percent lighter than an average MY 2017 vehicle, uses this design

methodology is interesting and relevant, this information, by itself, is insufficient to assess the amount of mass reduction that is feasible and the cost for the mass reduction. ICCT did not provide a comprehensive analysis showing a design concept that maintains vehicle attributes and performance, such as noise, vibration and harshness, stiffness, handling, compliance with NHTSA safety standards, good performance under NHTSA NCAP and IIHS rating systems, and other criteria. The various studies in Section I.E. considered those factors to varying degrees. Without that rigorous analysis, the actual amount of mass reduction that could be enabled through the use of those materials and methods described by ICCT, and the cost of achieving that mass reduction, would be highly speculative. As explained in Section I.E below, the agencies determined the NHTSA sponsored design studies remain a reasonable basis for estimating the feasible amount of mass reduction and the cost for mass reduction in the rulemaking timeframe, because those studies considered a wide range of materials (including advanced materials) and design solutions.

b) Analysis Fleet Mass Reduction Assignments

The agencies included an estimated level of mass reduction technology for each vehicle model in the MY 2016 analysis fleet for the NPRM, and have updated the estimates for the MY 2017 analysis fleet for the final rule analysis. The methodology used to provide each vehicle model an appropriate initial mass reduction technology level for further improvements was described in detail in the PRIA accompanying the NPRM, and is reproduced here, in part, to provide additional context to the agencies' responses to comments on analysis fleet mass reduction assignments. The methodology used in this final rule was unchanged from the NPRM.

As an overview, the agencies developed regression models to estimate curb weights based on other observable attributes. With regression outputs in hand, the agencies evaluated the distribution of vehicles in the analysis fleet. In addition, vehicle platforms were evaluated based on the sales-weighted residual of actual vehicle curb weights versus predicted vehicle curb weights. Based on the actual curb weights relative to predicted curb weights, platforms (and the subsequent vehicles) were assigned a baseline mass reduction level (MR0 through MR6). For the NPRM and final rule analysis, the agencies followed a similar procedure for the MY 2016 and MY 2017 analysis fleets.

To develop the curb weight regressions, the agencies grouped vehicles into three separate body design categories for analysis: 3-Box, 2-Box, and Pick-up.

Table VI-60 - Mass Reduction Body Styles Sets

3-Box	**2-Box**	**Pick-up**
Coupe	Hatchback	Pick-up
Sedan	Wagon	

Convertible	Sport Utility Minivan Van	

For the NPRM and final rule analysis, the agencies retained the MY 2015 regressions for 3-Box and 2-Box vehicles, however the pickup category regression was updated in response to comments on the Draft TAR. The agencies trained a new regression with EPA MY 2014 data and added pick-up bed length as an independent variable. As a result of stepping back to MY 2014 data for the pick-up regression, the training data did not include the all-aluminum body Ford F-150 in the calculation of the baseline. The advanced F-150 in the MY 2015 pick-up regression meaningfully affected Draft TAR regression statistics because the F-150 accounted for a large portion of observations in the analysis fleet, and the F-150 included advanced weight savings technology.

The agencies leveraged many documented variables in the analysis fleet as independent variables in the regressions. Continuous independent variables included footprint (wheelbase x track width) and powertrain peak power. Binary independent variables included strong HEV (yes or no), PHEV (yes or no), BEV or FCV (yes or no), all-wheel drive (yes or no), rear-wheel drive (yes or no), and convertible (yes or no). In addition, for PHEV and BEV/FCV vehicles, the capacity of the battery pack was included in the regression as a continuous independent variable. In some body design categories, the analysis fleet did not cover the full spectrum of independent variables. For instance, in the pickup body style regression, there were no front-wheel drive vehicles in the analysis fleet, so the regression defaulted to all-wheel drive and left an independent variable for rear-wheel drive.

Furthermore, the agencies evaluated alternative regression variables in response to comments from vehicle manufacturers on the NHTSA/Volpe analysis in Draft TAR.[910] The agencies evaluated regressions including overall dimensions of vehicles, such as height, width, and length, instead of and in addition to just wheelbase and track width. The experimental regression variables only marginally changed predicted curb weight residuals as a percentage of predicted curb weight, at an industry level and for most manufacturers. The results were not significantly different, and therefore the agencies opted not to add these variables to regressions or replace independent variables presented in Draft TAR with new variables.

Table VI-61 - Regression Statistics for Curb Weight (lbs.)

[table forthcoming]

Each of the three regressions produced outputs effective for identifying vehicles with a significant amount of mass reduction technology in the MY 2016 analysis fleet. Many coefficients for independent variables provided clear insight into the average weight penalty for

[910] [Cite comments].

the utility feature. In some cases, like battery size, the relatively small sub-sample size and high collinearity with other variables confounded coefficients.

By design, no independent variable directly accounted for the degree of weight savings technology applied to the vehicle. Residuals of the regression captured weight reduction efforts and noise from other sources.

The agencies received many comments on the Draft TAR encouraging the use of observed technologies in each vehicle, and in each vehicle subsystem to assign levels of mass reduction technology. As a practical matter, the agencies cannot conduct a tear down study and detailed cost assessment for every vehicle in every model year. However, upon review of many vehicles and their subsystems, the agencies recognized a few vehicles with MR0 or MR1 assignments in NHTSA's analysis of the Draft TAR that contained some advanced weight savings technologies, yet these vehicles and their platforms still produced ordinary residuals. Engineers from industry confirmed important factors other than glider weight savings and the independent variables considered in the regressions may factor into the use of lightweight technologies. Such factors included the desire to lower the center of gravity of a vehicle, improve the vehicle weight distribution for handling, optimize noise-vibration-and-harshness, increase torsional rigidity of the platform, offset increased vehicle content, and many other factors. In addition, engineers highlighted the importance of sizing shared components for the most demanding applications on the vehicle platform; optimum weight savings for one platform application may not be suitable for all platform applications. For future analysis, the agencies will look for practical ways to improve the assessment of mass reduction content and the forecast of incremental mass reduction costs for each vehicle.

Figure VI-24 below shows results from the pickup truck regression on predicted curb weight versus actual curb weight. Points above the solid regression line represent vehicles heavier than predicted (with lower mass reduction technology levels); points below the solid regression line represent vehicles lighter than predicted (with higher mass reduction technology levels). The dashed lines in the Figure VI-24 show the thresholds (5, 7.5, 10, 15, 20 and 28 percent of glider weight). Final rule glider weight assumption is 71 percent of vehicle curb weight.

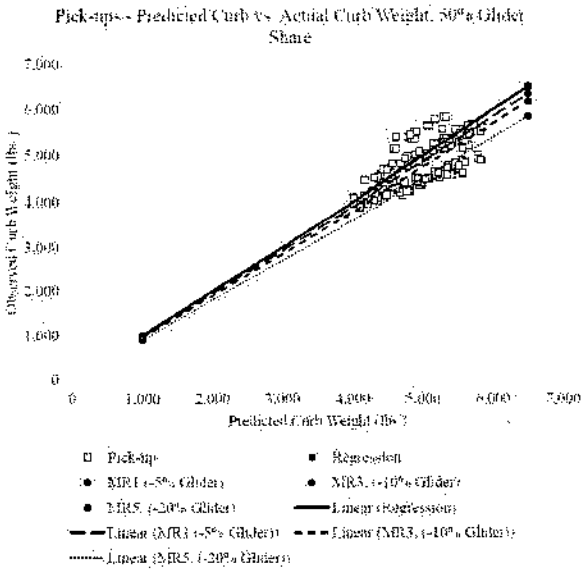

Figure VI-24 - Observed Curb Weight vs. Actual Curb Weight for the MY 2017 Analysis Fleet, and Glider Mass Reduction Technology Thresholds for 71 Percent Glider Share of Curb Weight

For points with actual curb weight below the predicted curb weight, the agencies used the residual as a percent of predicted weight to get a sense for the level current mass reduction technology used in the vehicle. Notably, vehicles approaching -20% curb weight widely use advanced composites throughout major vehicle systems, and a few examples exist in the MY 2016 fleet.[911]

Generally, residuals of regressions as a percent of predicted weight appropriately stratified vehicles by mass reduction level. Most vehicles showed near zero residuals or had actual curb weights close to the predicted curb weight. Few vehicles in the analysis fleet were identified with the highest levels of mass reduction. Most vehicles with the largest negative residuals have demonstrably adopted advanced weight savings technologies at the most expensive end of the cost curve.

To validate the residuals, the agencies estimated the mass reduction technology level for several vehicle models in the analysis fleet and compared those estimates to the numerical results from the regression analysis. To estimate the mass reduction technology level for the selected vehicles, the agencies conducted an in-depth review of available information on the materials,

[911] This evidence suggests that achieving a 20% curb weight reduction for a production vehicle with a baseline defined with this methodology is extremely challenging, and requires very advanced materials and disciplined design.

design, and last redesign year for those vehicle models, and compared that information with the designs and materials used in the mass reduction feasibility and cost studies summarized in Section [MR Costs], below. That comparison showed good agreement with the technology levels from the regression analysis.

The agencies believe the regression methodology is a technically sound methodology for estimating mass reduction levels in the analysis fleet.

As part of their comments stating the NPRM modeling reflected reality better than the Draft TAR and Proposed Determination analyses, Toyota commented broadly that the MY 2016 baseline fleet used in the NPRM encompassed powertrain and tractive energy (including mass reduction) improvements more representative of vehicles on the road today.[912] Toyota noted that the 2016 baseline fleet generally contained higher levels of technology compared to the MY 2014 and MY 2015 baseline fleets, and included a comparison of its initial fleet mass reduction assignments in the Draft TAR and the NPRM. Toyota showed how moving further up the technology tree (e.g., starting with a baseline that includes higher levels of technology) for certain pathways such as mass reduction increased costs exponentially. Toyota stated that the NPRM underestimated mass reduction cost values.

While a more specific discussion of costs is located in Section [MR Costs Section], the agencies agree with Toyota's assessment that the costs for mass reduction technology increase exponentially as progressively higher levels of mass reduction are incorporated. Having an accurate assessment of baseline technology levels ensures that the subsequent application of technology and its associated costs is correctly accounted for.

C.A.R generally agreed with the regression methodology of using observed vehicle attributes for estimating mass reduction levels, as opposed to comparing vehicle curb weight from a newer model year to a previous generation of the same vehicle. Commenters pointed to several of the limitations discussed above.[913]

Both ICCT and H-D Systems commented on the methodology for identifying mass reduction technology levels in the analysis fleet, with ICCT broadly stating that by placing additional mass reduction technology in the baseline, the agencies artificially removed "the most cost-effective lightweighting from future use, which incorrectly increases the costs of all subsequent mass-reduction in the compliance modeling."[914]

ICCT claimed that the agencies unjustifiably increased the amount of vehicle mass reduction technology present in the 2016 baseline fleet from the 2015 baseline used in the Draft TAR, stating that the 2015 Draft TAR fleet had 26 percent of vehicles sold with some level of mass reduction applied (MR1 or a higher level), whereas the 2016 NPRM fleet had 47 percent of vehicles sold with some level mass reduction applied. In addition to faulting the agencies for not acknowledging the change and not attempting to justify it, ICCT stated that the 2016 analysis fleet mass reduction assignments were overstated, as "it appears that the agencies have applied

[912] NHTSA-2018-0067-12098.
[913] [CITE PER COMMENT BUBBLE.]
[914] NHTSA-2018-0067-11741 full comments.

mass reduction technology to vehicles in the model that did not have mass reduction applied in the real world." ICCT stated that the effect of this change was to "render[] unavailable mass reduction technologies for these vehicles in the model," causing the model to select less cost-effective technologies instead and driving the modeled compliance costs higher.

ICCT argued that to substantiate the changes made to the baseline fleet mass reduction assignments, the agencies must show data on how these improvements are evident in the fleet and to quantify and include their realized benefits in the analysis, including a detailed and justified explanation of all mass reduction technologies deemed already to have been applied to the MY 2016 analysis fleet. More specifically, ICCT stated that the agencies "must clearly and precisely share their estimated percent (and absolute pounds) mass reduction amount for each vehicle make and model in the baseline fleet (rather than simply showing binned categories), and their technical justification for each value," and "[t]o not do so obscures the agencies' new methods and data sources from public view, rendering their lightweighting calculations a black box."

In addition, ICCT recommended that the agencies conduct two sensitivity analyses, one assuming that every baseline make and model has not yet applied any lightweighting (setting the baseline to 0% mass reduction), and one assuming that each vehicle model has applied Draft TAR baseline mass reduction assignments, to demonstrate how much the agencies' decision to load up more baseline technology affects the compliance scenarios.

ICCT concluded that because the changes in baseline mass reduction assignments from prior analyses to the NPRM "are opaquely buried in the agencies' datafiles and unexplained, we believe the agencies have to reissue a new regulatory analysis and allow an additional comment period for review of their methods and analysis."

To address ICCT's comment, it is important to understand the mass reduction baseline technology assignment methodology previously used by EPA in the Draft TAR and Proposed Determination.[915] As stated in the Draft TAR, the curb weight of each vehicle model in the MY 2008 analysis fleet (used for the 2012 rulemaking to establish MYs 2017-2025 standards) was assumed to be at a baseline MR0 level. The mass reduction technology level in the MY 2014 analysis fleet was determined by comparing the curb weight of the MY 2014 vehicle to the most similar vehicle in the MY 2008 analysis fleet.[916] The curb weight of the newer model year vehicle was adjusted to account for changes in the vehicle footprint and changes in mass due to added safety technology. If a vehicle did not have a previous generation vehicle, then the sales weighted average percent mass reduction over the manufacturer's name plate product line was used to represent the expectation of mass reduction technology available within the vehicle.

EPA listed some limitations to this methodology in the Draft TAR,[917] and others are also addressed here. First, assuming that every vehicle started with MR0 technology did not account for the actual varying levels of mass reduction technology that existed in the MY 2008 fleet.

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[915] Citing required
[916] Drat TAR at 5-395
[917] Draft TAR at 5-395.

Second, for each vehicle model, there was no accounting for the mass associated with different powertrain configurations. This was particularly problematic because the method did not account for light weight technology already available in the vehicle structure to counter the increased mass associated with more advanced powertrains, such as HEV, PHEV, and EV technologies.[918] Third, there was no sales-weight accounting for the various configurations in estimating the vehicle model mass reduction technology level, meaning that if a high-sales-volume vehicle employed significant mass reduction technology, that vehicle was not credited as such in the analysis fleet. Fourth, there was no accounting for mass increases due to the addition of future regulatory requirements like potential safety regulations. Fifth, there was no accounting for mass associated with changes in vehicle attributes and utility, such as the addition of infotainment systems and crash avoidance technologies. These limitations all individually had the effect of overestimating mass reduction technology effectiveness and undercounting mass reduction technology costs across the fleet, and accordingly their combined effect was significant. The lack of controls for these items introduced errors into the mass reduction technology level effectiveness estimates.

After considering the comments, the agencies determined the use of the regression method, based on observable attributes, is the best available methodology to provide a reasonable estimate of mass reduction technology for the analysis fleet. The agencies believe that, contrary to ICCT's assertion, the regression methodology used in the NHTSA Draft TAR, NPRM, and final rule analyses provides a more transparent method for calculating baseline mass reduction technology assignments. The methodology was fully explained in the Draft TAR and PRIA, and avoided the limitations identified by EPA by using data from the analysis fleet, and not requiring the use of or assumptions about the exact mass reduction levels of vehicles in a prior model year fleet. In addition, the regression accounted for differences in powertrains between trim levels, including non-ICE powertrains by accounting for these factors in the regression analysis.

Also, because manufacturers generally apply mass reduction technology at a vehicle platform level (i.e. using the same components across multiple vehicle models that share a common platform) to leverage economies of scale and to manage component and manufacturing complexity, conducting the regression analysis at the platform level leads to more accurate estimates for the real-world vehicle platform mass reduction levels. The platform approach also addresses the impact of potential weight variations that might exist for specific vehicle models, as all of the individual vehicle models are aggregated into the platform group, and are effectively averaged using sales weighting, which minimizes the impact of any outlier vehicle configurations.

The agencies also disagree that the changes in baseline mass reduction assignments were unexplained. The PRIA discussed reasons that baseline mass reduction assignments differed from prior analyses, including that, "[s]ince the Draft TAR, many platforms have not been redesigned, but in some cases the sales-weighted residuals for carryover platforms have moved. In the case of 2-Box and 3-Box vehicles, the analysis attributes such changes to differences in

[918] PRIA at page 413

sales mix year-over-year and other updates to reported curb weights and platform designations. In the case of platforms with pick-up trucks, the analysis updated the pick-up regression since the Draft TAR, so that may be a contributing factor."[919]

To the extent that the NPRM glider weight assumption impacted the NPRM MY 2016 analysis fleet baseline mass reduction assignment values, the agencies presented a table in the PRIA showing how different glider weight assumptions impacted mass reduction technology levels for the analysis fleet.[920] The following Table VI-62Table VI-62 recreates that table in part, with updates based on the glider weight values used for the final rule.

For example, from the regression analysis, the Ford F-150 has a predicted curb weight (residual) of 12.4 percent of the actual curb weight. If the glider weight assumption is 50 percent of the vehicle curb weight (like in NPRM), then the agencies would assign MR5 as an initial mass reduction assignment in the analysis fleet. With this high level of mass reduction technology already applied, the opportunity for further mass reduction would be limited. However, if the glider weight is assumed to be 71 percent of the vehicle curb weight, then Ford F-150 would be assigned MR4, and would have an opportunity to apply another level of mass reduction albeit at higher cost.

Table VI-62 - Mass Reduction Technology Levels for the MY 2017 Analysis Fleet for 50% and 71% Glider Share of Curb Weight

CAFE Model Platform Code	Example Code	Mass Reduction Residual (%)	Mass Reduction Level for 71% Glider Weight (Final Rule)	Mass Reduction Level for 50% Glider Weight (NPRM)
Li8	BMW i8	-23.0%	MR6	MR5
Lamborghini-A	Aventador	-17.4%	MR6	MR5
Alfa	Alfa Romeo 4C	-23.2%	MR6	MR5
Li8	BMW i3 94 R19	-18.4%	MR5	MR5
Omega	Cadillac CT6	-14.4%	MR4	MR5
Y-CAR/Y1XX	Chevrolet Corvette	-12.5%	MR4	MR5
T3	Ford F-150	-12.4%	MR4	MR5
RamVan	Ram ProMaster	-12.0%	MR4	MR5
Lamborghini-H	Huracan	-11.7%	MR4	MR5
Global Epsilon/E2XX	Chevrolet Malibu	-11.2%	MR4	MR5
NBC(2)	Toyota Prius C	-15.5%	MR3	MR5
SKYACTIV R	Mazda MX-5	-14.4%	MR3	MR5
MODEL S	Tesla Model S	-11.3%	MR3	MR5

[919] PRIA at 424.
[920] PRIA at 422.

V	Nissan Versa	-10.8%	MR3	MR5
II	Honda Civic	-10.6%	MR3	MR5
Basic(K-Basic1)	Kia Soul	-10.0%	MR3	MR5

The agencies also disagree that the amount of vehicle mass reduction technology present in the 2016 baseline fleet was "unjustifiably increased" from the 2015 baseline used in the Draft TAR. Table VI-63Table VI-63 shows the percent mass reduction technology used in Draft TAR, NPRM, and in final rule. It is clear from the table below that total percentage of MY 2016 vehicle fleet used in the NPRM had nearly the same level of some mass reduction technology applied compared to the Draft TAR. Similar to ICCT's observations, 28 percent of the MY 2015 vehicle fleet used in the Draft TAR had some level of mass reduction technology (MR1 to MR5) and 26 percent of MY 2016 vehicle fleet had some mass reduction technology applied. Since the agencies assumed a reduced glider share in the NPRM, the percentage of vehicles assigned a MR4 or MR5 technology level increased compared to Draft TAR. In addition, for this final rule, the agencies observed that many of the vehicles in the MY 2017 fleet had been redesigned, which provided the opportunity to incorporate additional mass reduction technologies.

Table VI-63 - Mass Reduction Assignment

		Draft TAR	**NPRM**	**Final Rule**
	Percentage glider weight reduction	**75% Percent glider**	**50 percent glider**	**71 percent glider**
MR0	0%	72.00%	73.01%	57.18%
MR1	5%	11.93%	7.68%	15.62%
MR2	7.5%	8.35%	3.30%	7.66%
MR3	10%	6.91%	5.88%	7.79%
MR4	15%	0.56%	5.34%	11.42%
MR5	20%	0.25%	4.80%	0.10%
MR6	28%	0.00%	0.00%	0.03%

The agencies also declined to conduct sensitivity analyses assuming each vehicle's baseline is set to 0% mass reduction and assuming each vehicle model has applied the Draft TAR baseline mass reduction assignments. First, MY 2017 production vehicles clearly employed varying levels of mass reduction technologies. Assuming every vehicle in the analysis fleet is set to 0 percent mass reduction improvement would not demonstrate how the agencies' decision to assign technology levels in the analysis fleet affected the compliance scenarios. Allowing vehicles in the analysis fleet artificially to achieve more mass reduction improvements than

could actually be achieved in the real world would result in artificially overstated effectiveness improvements and understated costs to achieve higher stringency levels.

Second, as discussed above, EPA's Draft TAR baseline mass reduction assignments had identified limitations that the regression methodology has addressed. Moreover, as discussed above, the regression methodology was updated from the Draft TAR to characterize data better on pickup trucks. The agencies do not believe that conducting sensitivity analyses using these outdated or limited assumptions would be useful for this final rule.

More narrowly, H-D Systems commented that while the regression coefficients between 2-box and 3-box vehicles for footprint seemed consistent, the regression coefficients for horsepower between the 2-box and 3-box vehicles seemed incorrect because both types of vehicles use similar engines.[921] HDS stated that "[c]ollinearity between footprint and HP or other effects caused by having electric vehicles (with electric motor HP ratings) in the regression data is the probable cause of these inconsistent coefficients for HP, but this cannot be confirmed without access to the same database used by NHTSA." HDS concluded that "[r]evisions to the regression could have a significant effect on the baseline assignment of vehicles, as the current assignment for vehicles like the 2016 Mazda MX5 as having the highest level of weight reduction technology (MR5) and the 2016 Chevy Malibu as having MR4 technology appear incorrect as their curb weights are comparable to other similar MY 2016 vehicles in their respective class."

While many of the vehicles share same the same powertrain for passenger cars and SUVs or for cars and pickup trucks, the utility and functionality of the vehicle in SUVs and pickup trucks (2-box) is different than passenger cars (3-box). The presence of additional structure for towing or higher capacity towing, rear cross member, higher capacity suspension, and other differences, enable SUVs and Pickup trucks to have towing and heavier payload capability. For example, Ford uses the nearly similar displacement and horsepower engines in Mustang Ecoboost Coupe and in F150 2WD XL, Regular Cab, Long Box. However, the curb weight for the pickup truck is higher than the Mustang. Directionally, this supports that the 2-box weight per horsepower coefficient should be greater than the 3-box coefficient, just as it is in the for the regression. The coefficient for passenger cars and SUVs has not changed since the Draft TAR (based on MY2015 vehicle fleet). Based on the comments to Draft TAR, for the NPRM, a new set of coefficients were generated for pickups using the MY 2014 vehicle fleet. This was done so that coefficients are not skewed due to presence of the aluminum intensive Ford F150 pickup truck. Hence, the agencies believe the coefficients used in the regression analysis are directionally correct and disagree with HDS's assertion. We further note that HDS did not suggest any alternate methodology or specific coefficients to use in the regression analysis.

c) Mass Reduction Technology Adoption Features

The agencies described in the NPRM that given the degree of commonality among the vehicle models built on a single platform, manufacturers do not have complete freedom to apply unique technologies to each vehicle that shares the platform: while some technologies (e.g. low

[921] NHTSA-2018-0067-11985 (HD Systems).

rolling resistance tires) are very nearly "bolt-on" technologies, others involve substantial changes to the structure and design of the vehicle, and therefore often necessarily affect all of the vehicle models that share that platform. In most cases, mass reduction technologies are applied to platform level components and therefore the same design and components are used on all of the vehicle models that share the platform.

As discussed in Section [CAFE model logic section], above, each vehicle in the analysis fleet is associated with a specific platform. Similar to the application of engine and transmission technologies, the CAFE model defines a platform "leader" as the vehicle variant of a given platform that has the highest level of observed mass reduction present in the analysis fleet. If there is a tie, the CAFE model begins mass reduction technology on the vehicle with the highest sales in model year 2017. If there remains a tie, the model begins by choosing the vehicle with the highest Manufacturer Suggested Retail Price (MSRP) in MY 2017. As the model applies technologies, it effectively levels up all variants on a platform to the highest level of mass reduction technology on the platform. So, if the platform leader is already at MR3 in MY 2017, and a "follower" starts at MR0 in MY 2017, the follower will get MR3 at its next redesign (unless the leader is redesigned again before that time, and further increases the mass reduction level associated with that platform, then the follower would receive the new mass reduction level).

Important for analysis fleet mass reduction assignments (discussed above), and for understanding adoption features as well, is the agencies' handling of vehicles that traditionally operated on the same platform but had a mix of old and new platforms in production when the analysis fleet was created. As described in the PRIA, the Honda Civic and Honda CR-V traditionally share the same platform. In MY 2016, Honda redesigned the Civic and the updated platform, which included many mass reduction technologies. Also in MY 2016, Honda continued to build the CR-V on the previous generation platform – a platform that did not include many of the mass reduction technologies on the all new MY 2016 Civic. In MY 2017, Honda launched the new CR-V that incorporated changes to the Civic platform, and the Civic and CR-V again shared the same platform with common mass reduction technologies. The NPRM and final rule analyses treat the old and new platforms separately to assign technology levels in the baseline, and the CAFE model brings vehicles on the old platform up to the level of mass reduction technology on the new shared platform at the first available redesign year.

Furthermore, as stated in the NPRM and PRIA, unlike the analysis presented in the Draft TAR that restricted high levels of mass reduction for cars to show a safety neutral pathway to compliance, the NPRM analysis did not artificially restrict mass reduction to achieve a safety neutral outcome.[922] The NPRM CAFE model considered MR0 through MR5 for all vehicles at redesign, and similarly for the final rule, the CAFE model considers MR0 through MR6 for all vehicles at redesign.

Ford commented in support of the removal of "previously applied modeling rules that disallowed the mass reduction technology pathway for certain vehicle classes since this

[922] PRIA at 494.

restriction was not supported by an adequate technical justification."[923] ICCT commented that a constraint of 7.5 percent mass reduction to smaller cars, as was applied in the Draft TAR, would be appropriate for those vehicles.

The agencies considered ICCT's comment that mass reduction on small passenger cars should be limited to 7.5 percent, and Ford's comment supporting the removal of "previously applied modeling rules that disallowed the mass reduction technology pathway for certain vehicle classes." Neither CAFE standards nor this analysis mandate mass reduction, or mandate that mass reduction occur in any specific manner. The mass reduction cost subsection below shows mass reduction is a cost-effective technology for improving fuel economy and CO_2 emissions. The steel, aluminum, plastics, composite, and other material industries are developing new materials and manufacturing equipment and facilities to produce those materials. In addition, suppliers and manufacturers are optimizing designs to maintain or improve functional performance with lower mass. Manufacturers have stated that they will continue to reduce vehicle mass to meet more stringent standards, and therefore, this expectation is incorporated into the modeling analysis supporting the standards to: (1) determine capabilities of manufacturers; and (2) predict costs and fuel consumption effects of CAFE standards. The CAFE and CO_2 rulemakings in 2012, and the Draft TAR and EPA Proposed Determination, imposed an artificial constraint that limited vehicle mass reduction in some small vehicles to achieve a desired safety-neutral outcome. For the current rulemaking, this artificial constraint is eliminated so the analysis reflects manufacturers' applying the most cost effective technologies to achieve compliance with the regulatory alternatives and the final standards; this approach allows mass reduction to be applied across the fleet. This approach is consistent with industry trends. To the extent that mass reduction is only cost-effective for the heaviest vehicles, the CAFE model would create the outcome predicted by commenters. In reality, however, mass reduction is a cost-effective means of improving fuel economy and does take place across vehicles of all sizes and weights. Accordingly, the model reflects that manufacturers may reduce vehicle mass—regardless of vehicle class—when doing so is cost effective.

The agencies have included one additional mass reduction level for the final rule in response to comments by ICCT and others, and to account for carbon fiber use in vehicles. For the NPRM, the maximum level of mass reduction was limited to 10 percent of a vehicle's curb weight, and that amount of mass reduction could be applied during the rulemaking timeframe. For the final rule, based on the current state of mass reduction technology and the application rate of different levels of mass reduction technologies, the agencies applied phase-in caps for MR5 and MR6 (15 percent and 20 percent reduction of a vehicle's curb weight, respectively). The agencies applied a phase-in cap for MR5 level technology so that 15 percent of the vehicle fleet starting in 2016 employed the technology, and the technology could be applied to 100 percent of the fleet by MY 2022. This cap is consistent with the NHTSA lightweighting study that found that a 15 percent curb weight reduction for the fleet is possible within the rulemaking timeframe.[924] The agencies also applied a phase in cap for MR6 technology so that one percent of the vehicle fleet starting in MY2016 employed the technology, and the technology could be applied to 13 percent of the fleet by MY2025. The agencies believe that this phase-in cap

[923] NHTSA-2018-0067-11928

[924] DOT HS 811 666: Mass Reduction for Light Duty Vehicles for Model Years 2017-2025; Figure 397 at page 356.

appropriately functions as a proxy for the cost and complexity currently required (and that likely will continue to be required until manufacturing process evolve) to produce carbon fiber components. Again, MR6 technology in this analysis reflects the use of a significant share of carbon fiber content, as seen through the BMW i3 and Alfa Romeo 4c as discussed above.

d) Mass Reduction Technology Effectiveness

As discussed in Section [Overview Technology Effectiveness], ANL developed a database of vehicle attributes and characteristics for each vehicle technology class that included over 100 different attributes like frontal area, drag coefficient, fuel tank weight, transmission housing weight, transmission clutch weight, hybrid vehicle component weights, and weights for components that comprise engines and electric machines, tire rolling resistance, transmission gear ratios, and final drive ratio. ANL used these attributes to "build" each vehicle that it used for the effectiveness modeling and simulation. Important for precisely estimating the effectiveness of different levels of mass reduction is an accurate list of initial component weights that make up each vehicle subsystem, from which Autonomie considered potential mass reduction opportunities.

As stated above, glider weight, or the vehicle curb weight minus the powertrain weight, is used to determine the potential opportunities for weight reduction irrespective of the type of powertrain.[925] This is because weight reduction can vary depending on the type of powertrain. For example, an 8-speed transmission may weigh more than a 6-speed transmission, and a basic engine without variable valve timing may weigh more than an advanced engine with variable valve timing. Autonomie simulations account for the weight of the powertrain system inherently as part of the analysis, and the powertrain mass accounting is separate from the application and accounting for mass reduction technology levels (MR0-MR6) that are applied to the glider in the simulations. Similarly, Autonomie also accounts for battery and motor mass used in hybrid and electric vehicles separately. This secondary mass reduction is discussed further, below.

Accordingly, in the Autonomie simulation, mass reduction technology is simulated as a percentage of mass removed from the specific subsystems that make up the glider, as defined for that set of simulations (including the non-powertrain secondary mass systems such as the brake system).

(1) Glider Mass and Mass Reduction

Autonomie accounts for the mass of each subsystem that comprises the glider. For the NPRM, the glider subsystems included the vehicle body and the chassis, but did not include mass from subsystems such as the interior system, brake system, electrical accessory system, and steering and wheel systems. The agencies described in the PRIA that based on advances in active and passive safety technologies that add some mass to the interior system, certain subsystems were not considered for potential light-weighting to maintain safety performance.[926]

[925] Depending on the powertrain combination, the total curb weight of the vehicle includes glider, engine, transmission and/or battery pack and motor(s).
[926] PRIA at 411-412

For the NPRM, the A2Mac1 database was used to estimate the average mass of each subsystem considered as part of the glider based on the subsystem assumptions, and to compute the average glider share of vehicle curb weight.[927] That analysis showed the glider accounted for 50 percent of the vehicle curb weight. The agencies solicited comment on whether systems or components beyond the vehicle body and chassis should be included as part of the glider, and also indicated that the glider weight assumption might increase for the final rule based on further research.

The agencies received several comments on the NPRM glider weight assumptions, with the overarching theme of the comments being that the NPRM did not include all systems and components that should be included, and if those systems and components were included, the glider share would be higher. Commenters also stated that the 50 percent glider share value used for the NPRM reduced the amount of mass reduction that could be applied to vehicles in the analysis.

UCS stated that representing the glider as a reduced fraction of the curb weight caused the agencies significantly to underestimate the potential for mass reduction. UCS noted that because mass reduction is applied at the glider level, reducing the share of the glider inherently caps the potential reduction in the curb weight, and this single change cut the potential improvement from mass reduction by one-third. Similarly, CARB stated that the updated glider weight assumption severely limited the effectiveness of mass reduction, as the most aggressive mass reduction category of 15 to 20 percent mass reduction can only reduce the vehicle curb weight by 10 percent.

UCS cited previous agency analyses and analyses from other organizations that stated the total potential for mass reduction by 2025 is between 15.8 and 32 percent of curb weight, contrasted to the NPRM assumption of a maximum 10 percent reduction.[928] UCS also cited industry data which showed that the glider represented a higher share of vehicle curb weight than was assumed in the Draft TAR analysis, and both UCS and CARB cited to industry data from vehicles like the Ford F-150, which UCS stated was able to achieve the NPRM maximum achievable mass reduction through the deployment of aluminum alone.[929] UCS concluded that by capping the total potential for mass reduction at such a low level, the agencies artificially reduced the potential for the cost-effective technology, which increased the use of more expensive and more advanced technologies. CARB concluded that the agencies' 10 percent restriction means that real-world improvements that have already happened on production vehicles were not considered feasible in the NPRM analysis.

Several commenters also stated that the 50 percent glider weight assumption was unexplained and unjustified, and argued that the agencies' own studies showed that the glider weight percentage should range from 75-80 percent.[930] UCS stated that both the NHTSA-

[927] The A2Mac1 database was used and this analysis was presented in ANL report docketed here: NHTSA-2018-0067-1490. The mass data in the database were obtained from actual teardown of vehicles.
[928] NHTSA-2018-0067-12039 (citing Caffrey et al. 2013, Caffrey et al. 2015, Lotus 2012, NAS 2015, Singh et al. 2012, Singh et al. 2016, Singh et al. 2018).
[929] NHTSA-2018-0067-12039. See also NHTSA-2018-0067-11873
[930] NHTSA-2018-0067-11985; NHTSA-2018-0067-12039; NHTSA-2018-0067-11873.

sponsored 2011 Honda Accord study, which showed the glider making up 79 percent of the vehicle, and the NHTSA-sponsored 2014 Chevrolet Silverado study, which showed the glider making up 73.6 percent, showed values substantially higher than the 50 percent value, and were in line with the agencies' prior analyses.[931] As part of its comments that key assumptions about mass reduction changed from the Draft TAR without any supporting rationale, CARB stated that EPA had previously relied on four studies (two contracted for by EPA and two contracted for by NHTSA), and for the NPRM analysis the agencies only cited two of those studies.[932] Moreover, ICCT commented that the agencies' previous studies showed a glider fraction greater than 75 percent even with numerous safety features considered. Accordingly, ICCT stated that the agencies must specifically identify the "safety components" referred to in the NPRM and justify the limitations placed on light weighting in response. ICCT affirmatively concluded that the agencies must re-adopt the Draft TAR methodology in which glider mass is assumed to be 75 percent of vehicle mass, or provide detailed justification and evidence supporting the new value of 50 percent.[933]

The agencies carefully considered these comments and reexamined available data and information. The agencies agree it is appropriate to reconsider the glider share for the final rule analysis. The NHTSA-sponsored passenger car light weighting study showed a glider mass of 79 percent, and the NHTSA-sponsored light duty truck light weighting study showed a glider mass of 73.6 percent. Also, the 75 percent glider weight used for the Draft TAR was a value between the values from these two studies. As these are just two vehicle models in the overall fleet of over 2900 vehicle models, the agencies determined it would be more rigorous to consider data from a broader array of vehicles with various powertrain combinations and trim levels, to assess the glider share for the final rule.

The agencies examined glider weight data available in the A2Mac1 database.[934] The A2Mac1 database tool is widely used by industry and academia to determine the bill of materials and mass of each component in the vehicle system.[935] The A2Mac1 database has been used by the agencies to inform past CAFE and CO_2 rulemakings. We analyzed a total of 147 MY 2014 to 2016 vehicles, covering 35 vehicle brands with different powertrain options representing a wide array of vehicle classes to determine the glider weight for the final rule analysis.[936]

The agencies also considered that the NHTSA passenger car and light truck light-weighting studies examined mass reduction in the body, chassis, interior, brakes, steering, electrical accessory, and wheels subsystems and had developed costs for light weighted components in those subsystems. As a result, the agencies determined it is appropriate to include all of those subsystems as available for mass reduction as part of the glider. Therefore all of these systems were included for the analysis of glider weight using the A2Mac1 database. Table

[931] NHTSA-2018-0067-12039
[932] NHTSA-2018-0067-11873
[933] NHTSA-2018-0067-11741
[934] A2Mac1: Automotive Benchmarking. (n.d.). Retrieved from https://a2mac1.com
[935] Bill of material (BOM) is a list of the raw materials, sub-assemblies, parts and quantities needed to manufacture an end product.
[936] [Refer to ANL report posted in the docket NHTSA-2018-0067-1490 for distribution of glider weight for different vehicle class which supports glider weight range from 66% to 73% of vehicle curb weight]

VI-64Table VI-64 shows the average mass for each subsystem and the glider share for each of the vehicle classes for all powertrain combinations.

Table VI-64 – Glider mass share assessment for the final rule analysis using A2Mac1 data

	1	2	3	4	5	6	7	8	9	10
Vehicle Class	Avg. Body Mass	Avg. Chassis Mass	Avg. Interior Mass	Avg. Brakes Mass	Avg. Steering Mass	Avg. Electrical Accessory Mass	Avg. Wheels Mass	Avg. Glider Mass (Sum of 1 to 7)	Avg. Curb Weight	% Glider Share
Compact Non-Performance	525.00	160.00	150.00	50.13	20.00	30.26	42.00	977.40	1338.71	73.01%
Compact Performance	525.00	160.00	200.00	55.12	22.00	35.25	45.00	1042.37	1455.85	71.60%
Midsize Non-Performance	650.00	200.00	175.00	60.13	25.00	30.26	54.00	1194.40	1611.24	74.13%
Midsize Performance	650.00	200.00	200.00	65.12	28.00	40.25	57.00	1240.37	1734.89	71.50%
Small SUV Non-Performance	650.00	200.00	180.00	60.13	25.00	30.26	60.00	1205.40	1651.09	73.01%
Small SUV Performance	650.00	200.00	220.00	75.12	28.00	40.25	66.00	1279.37	1792.46	71.38%
Midsize SUV Non-Performance	650.00	200.00	200.00	70.13	30.00	30.26	66.00	1246.40	1754.57	71.04%
Midsize SUV Performance	750.00	225.00	240.00	75.12	30.00	50.25	78.00	1448.37	2045.42	70.81%
Pickup Non-Performance	650.00	300.00	160.00	90.12	30.00	80.47	78.00	1388.58	2020.13	68.74%
Pickup Performance	800.00	350.00	200.00	95.11	30.00	100.44	90.00	1665.55	2345.18	71.02%
									Average	71.62%

This data was also compared with the glider weight measured in the NHTSA MY 2014 Chevrolet Silverado light weighting study,[937] and the glider weight data range was similar to the analysis results. Based on the comments and the agencies' updated assessment, we have increased the glider weight assumption to 71 percent of the vehicle curb weight for the final rule.

As stated above, for the NPRM, the interior, brake system, electrical accessory system, and steering and wheel systems were not included as part of the glider. The decision not to include the interior system was based on an assumption at that time that interior system mass reduction might adversely impact safety. In addition, the decision not to include the brake

[937] DOT HS 812 487: Mass Reduction for Light-Duty Vehicles for Model Years 2017–2025

system was based on an assumption at that time that there would be little or no opportunity for downsizing and reducing mass based on the reduced weight from body and chassis only. As a result, brake systems were not considered as part of the glider in the NPRM. For the final rule, we included the interior system based on market observations that light-weighted seats, side door trim, frontal dash, and others interior components have been incorporated on production vehicles that meet FMVSS standards and perform well on voluntary NCAP and IIHS safety tests. The agencies also considered that interior, brakes, steering, wheel and electrical subsystems were included in the NHTSA light weighting studies. By adding the interior, steering, wheel subsystems and electrical subsystems as part of glider, the agencies believe light weighting the glider increases the opportunity for brake system optimization and mass reduction. Similarly, there is increased opportunity for mass reduction for wheels using gauge optimization, resulting from including more subsystems in the glider.

By including the interior, brake, steering, electrical accessory, and wheel subsystems in addition to the body and chassis subsystems in the definition of what subsystems comprise the glider, we increased the glider weight from 50 percent of the vehicle curb weight to 71 percent of the vehicle curb weight. This increase in turn means that the potential for vehicle mass reduction was increased from 10 percent of the vehicle curb weight to 20 percent of the vehicle curb weight. Table VI-65Table VI-65 shows the percent of light truck glider weight reduction and the corresponding vehicle curb weight reduction for each level of mass reduction for the glider shares used in the Draft TAR (75 percent), NPRM (50 percent), and final rule (71 percent) analyses.[938]

Table VI-65 - Light Truck Glider Weight and Curb Weight Comparison for the Draft TAR, NPRM and Final Rule

	Glider Weight Percentages by MR Level	**Percent of Curb Weight for Light Trucks**		
		Draft TAR 75% glider share	NPRM 50% glider share	Final Rule 71% glider share
MR0	0.0%	0.00%	0.00%	0.00%
MR1	5.0%	3.75%	2.50%	3.55%
MR2	7.5%	5.63%	3.75%	5.33%
MR3	10.0%	7.50%	5.00%	7.10%
MR4	15.0%	11.25%	7.50%	10.65%
MR5	20.0%	15.00%	10.00%	14.20%
MR6	28.2%	21.15%		20.00%

[938] Table 6-57 in PRIA showed the vehicle curb weight changes for different glider weight assumptions.

(2) Powertrain Mass Reduction

As explained above, any mass reduction due to powertrain improvements is accounted for separately from glider mass reduction. Autonomie considers several components for powertrain mass reduction, including engine downsizing, and transmission, fuel tank, exhaust systems, and cooling system lightweighting.

The 2015 NAS report suggested an engine downsizing opportunity exists when the glider mass is lightweighted by at least 10%. The 2015 NAS report also suggested that 10% lightweighting of the glider mass alone would boost fuel economy by 3% and any engine downsizing following the 10% glider mass reduction would provide an additional 3% increase in fuel economy.[939] The agencies' lightweighting studies applied engine downsizing (for some vehicle types but not all) when the glider weight was reduced by 10 percent. Accordingly, the NPRM analysis limited engine resizing to several specific incremental technology steps;[940] important for this discussion, engines in the analysis were only resized when mass reduction of 10% or greater was applied to the glider mass, or when one powertrain architecture was replaced with another architecture.

ANL performed a regression analysis of engine peak power versus weight for the NPRM based on attribute data taken from the A2Mac1 benchmarking database, to account for the difference in weight for different engine types. For example, to account for weight of different engine sizes like 4-cylinder versus 8-cylinder, ANL developed a relationship curve between peak power and engine weight based on the A2Mac1 benchmarking data. For the NPRM analysis, this relationship was used to estimate mass for all engine types regardless of technology type (e.g., variable valve lift and direct injection). Weight associated with changes in engine technology was applied by using this linear relationship between engine power and engine weight from the A2Mac1 benchmarking database. When a vehicle in the analysis fleet with an 8-cylinder engine adopted a more fuel efficient 6-cylinder engine, the total vehicle weight would reflect the updated engine weight with two less cylinders based on the peak power versus engine weight relationship.

When Autonomie selects a powertrain combination for a lightweighted glider, the engine and transmission are selected such that there is no degradation in the performance of the vehicle relative to the baseline vehicle. The resulting curb weight is a combination of the lightweighted glider with the resized and potentially new engine and transmission. This methodology also helps in accurately accounting for the cost of the glider and cost of the engine and transmission in the CAFE model. This is one of the fundamental differences between the analysis for this rulemaking the analysis for the Proposed Determination. For the Proposed Determination, the cost for mass reduction included mass reduction and cost reduction for one specific engine downsizing, and applied it to all vehicle classes without regard for performance and utility.

[939] National Research Council. 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, D.C. - The National Academies Press. https://doi.org/10.17226/21744
[940] 83 FR 43027.

There also was no accounting for the mass of other applied powertrains and the associated effectiveness impacts.

As explained in the introduction, secondary mass reduction is possible from some of the components in the glider after mass reduction has been incorporated in primary subsystems (body, chassis, and interior). Similarly, engine downsizing and powertrain secondary mass reduction is possible after certain level of mass reduction is incorporated in the glider. For the analysis, we include both primary mass reduction, and when there is sufficient primary mass reduction, additional secondary mass reduction. The Autonomie simulations account for the aggregate of both primary and secondary glider mass reduction, and separately for powertrain mass.

The agencies received several comments about secondary mass reduction and powertrain mass reduction. Broadly, CARB commented that the agencies did not include powertrain downsizing and associated secondary mass reduction, which was a departure from the analysis done by EPA for the Draft TAR.[941] CARB stated that the agencies "inexplicably" did not consider secondary mass reduction opportunities "including but not limited to drive axles, suspension, and braking components (as a result of the overall vehicle being lighter); fuel tank (and corresponding weight of fuel during certification testing); powertrain (lighter engine and transmission needed to power the lighter vehicle); and thermal systems." CARB cited both EPA and NHTSA light weighting studies for the proposition that there are significant opportunities for secondary mass reduction that lead to additional cost savings. As a result, CARB stated that the agencies inflated the cost of mass reduction as well as the amount of mass reduction that is feasible and cost-effective, leading to an over estimate in the technology costs to meet the existing standards.

As CARB correctly noted, the NHTSA-sponsored studies have taken into consideration secondary mass reduction benefits such as radiator engine support, and optimized engine cradles, wheels, and suspension systems. As discussed above, in response to comments, the agencies have included additional subsystems such as brakes, wheels, steering, electrical, and interior systems to the glider for the final rule analysis, thereby accounting for mass reduction opportunities for these systems.

Also, as discussed further in [Section Mass Reduction Costs], below, secondary mass reduction is integrated into the mass reduction cost curves. Specifically, the NHTSA studies, upon which the cost curves were built, first generated costs for lightweighting the vehicle body, chassis, interior, and other primary components, and then calculated costs for lightweighting secondary components. Accordingly, the cost curves reflect that, for example, secondary mass reduction for the brake system is only applied after there has been sufficient primary mass reduction to allow the smaller brake system to provide safe braking performance and to maintain mechanical functionality.

CARB appears to have misunderstood how the analysis accounts for powertrain mass reduction. The agencies described in the PRIA that the Autonomie simulations recognize that

[941] NHTSA-2018-0067-11873.

many powertrain packages have different weights for each vehicle class; for example, an eight-speed transmission may weigh more than a six-speed transmission, and a basic engine with variable valve timing may weigh more than a basic engine without variable valve timing.[942] Autonomie varies the weight of these powertrain systems as part of the analysis, and these changes are done separately from the glider mass reduction technology levels (MR0 to MR6) in the simulations. Accordingly, accounting for powertrain mass reduction as part of the mass reduction technology analysis would double count impacts. The use of separate accounting assures that the analysis accounts for mass associated with secondary mass reduction, and engine downsizing, as well as mass associated with each individual engine, transmission, and electrification technology. These mass changes were not accounted for in the Draft TAR and Proposed Determination analyses. Moreover, these are accounted for separately in the cost accounting, which is discussed further in the [Mass Reduction Costs] section, below.

HDS commented that some assumptions in the Autonomie modeling related to engine weight appeared incorrect, such as the assumption that a turbocharged 4-cylinder engine weighed the same as a DOHV V6 engine with 1.5 times the 4-cylinder's displacement, when in fact that engine is often 75 to 100 lbs. lighter.[943]

HDS also noted that "mass reduction assumes no reduction of powertrain weight for mass reduction levels of 2.5% and 5%. Mass reduction effectiveness therefore are somewhat more appropriate for reductions over 5% which apparently include some powertrain weight reduction. More transparency in the PRIA regarding powertrain weight changes will allow more detailed comment on engine weight assumptions used."

We agree with the comment that certain advanced engines could be lighter than a basic engine. For the final rule, the estimated mass levels for engines were updated, as discussed in Section [Tech Effectiveness and Modeling], based on the A2Mac1 database and other sources that provided more precise mass data for powertrain technologies. Also, we improved upon the precision of estimated engine weights by creating two curves to represent separately naturally aspirated engine designs and turbocharged engine designs.[944] This update resulted in two benefits. First, small naturally aspirated 4-cylinder engines that adopted turbocharging technology reflected the increased weight of associated components like ducting, clamps, the turbocharger itself, a charged air cooler, wiring, fasteners, and a modified exhaust manifold. Second, larger cylinder count engines like naturally aspirated 8-cylinder and 6-cylinder engines that adopted turbocharging and downsized technologies would have lower weight due to having fewer engine cylinders. For the final rule analysis, a naturally aspirated 8-cylinder engine that adopts turbocharging technology and is downsized to a 6-cylinder turbocharged engine appropriately reflects the added weight of the turbocharging components, and the lower weight of fewer cylinders. These refinements address the issues identified in HDS's comments.

[942] PRIA at 418.
[943] NHTSA-2018-0067-11985.
[944] [ANL Final Model Documentation for final rule analysis Chapter 5.2.9 Engine Weight Determination.]

Regarding HDS's second comment, as discussed in the NPRM, to address product complexity and economies of scale, engine resizing is limited to specific incremental technology changes that would typically be associated with a major vehicle or engine redesign.[945] As discussed further in [Section Performance Neutrality], the NPRM also referred to the 2015 NAS report conclusion that "[f]or small (under 5 percent [of curb weight]) changes in mass, resizing the engine may not be justified, but as the reduction in mass increases (greater than 10 percent [of curb weight]), it becomes more important for certain vehicles to resize the engine and seek secondary mass reduction opportunities."[946] In consideration of both the NAS report and comments received from manufacturers, the agencies determined it would be reasonable to allow allows engine resizing upon adoption of 7.1%, 10.7%, 14.2%, and 20% curb weight reduction, but not at 3.6% and 5.3%.[947] Resizing is also allowed upon changes in powertrain type or the inheritance of a powertrain from another vehicle in the same platform. The increments of these higher levels of mass reduction, or complete powertrain changes, more appropriately match the typical engine displacement increments that are available in a manufacturer's engine portfolio.

(3) Summary of Final Rule Mass Reduction Technology Effectiveness

Figure VI-25Figure VI-25 below shows the effectiveness (fuel economy improvements) when glider is light weighted by 10% and no engine downsizing for different class of vehicles across all powertrain combinations.

Figure VI-25 - PLACE HOLDER FOR BAR CHART

Figure VI-26Figure VI-26 shows effectiveness (fuel economy improvements) when glider is light weighted by 10% with engine is downsizing for different class of vehicles across all powertrain combinations.

Figure VI-26

[Text Forthcoming]

e) Mass Reduction Costs

The PRIA described the decision to use NHTSA's passenger car light weighting study based on a MY 2011 Honda Accord and NHTSA's full-size pickup truck light weighting study based on a MY 2014 Chevrolet Silverado to derive the estimated cost for each of the mass reduction technology levels.[948] The agencies relied on the results of those studies because they considered an extensive range of material types, material gauge, and component redesign while

[945] *See* 83 FR 43027 (Aug. 24, 2018).
[946] National Research Council. 2011. Assessment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, D.C. – The National Academies Press. *http://nap.edu/12924*.
[947] These curb weight reductions equate to the following levels of mass reduction as defined in the analysis: MR3, MR4, MR5 and MR6, but not MR1 and MR2; additional discussion of engine resizing for mass reduction can be found in Section [X.X].
[948] PRIA at 391; Table 6-38 and Table 6-41 in PRIA

taking into account real world constraints such as manufacturing and assembly methods and complexity, platform-sharing, and maintaining vehicle utility, functionality and attributes, including safety, performance, payload capacity, towing capacity, handling, NVH, and other characteristics. In addition, the agencies described that the baseline vehicles assessed in the NHTSA-sponsored studies were reasonably representative of baseline vehicles in the MY 2016 analysis fleet.[949] The agencies also noted they made the decision to rely on these studies after reviewing other agency, CARB, ICCT and industry studies.[950] The other studies often did not consider important factors, made unrealistic assumptions about key vehicle systems, and/or applied secondary mass reduction inappropriately, resulting in unrealistically low costs. The PRIA also described how the cost estimates derived from the NHTSA lightweighting studies were adjusted to reflect the NPRM glider share assumption.[951]

Furthermore, the agencies changed the cost of mass reduction accounting from a curb weight basis in the Draft TAR to glider weight basis in the NPRM.[952] Because the mass reduction studies provide mass reduction costs for the glider, this change enabled more direct use of cost curve data from the studies in the CAFE model. This change also allowed independent accounting for powertrain mass, which enabled the CAFE model to account more accurately for the unique mass of each of the powertrains that are available in each vehicle model. The cost of the engine, transmission, and electrification are accounted for separately from the glider in the CAFE model.

The agencies received several comments on the mass reduction costs used in the NPRM. FCA commented that the costs and benefits used the CAFE model were overly optimistic, stating that although its Ram 1500 pickup truck achieved several hundred pounds of weight reduction, the cost of achieving that weight reduction was greater than that used in the CAFE model.[953] Similarly, as mentioned above, Toyota commented that mass reduction cost values were underestimated.[954] Conversely, CARB, UCS, and the City of Oakland in California commented that the costs used for mass reduction in the NPRM overstated the cost of mass reduction. The agencies also received several comments relating to the studies used to develop the mass reduction cost curves, how the values from those curves were applied in the CAFE model, and costs for secondary mass reduction; those comments are discussed in turn.

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[949] PRIA at 403.

[950] As described in the PRIA at 390-91, studies by EPA, CARB, Transport Canada, the American Iron and Steel Institute (AISI), the Aluminum Association, and the American Chemistry Council were all reviewed for potential incorporation into the analysis.

[951] See PRIA at 396, Tables 6-38 and 6-39; PRIA at 401, Tables 6-41 and 6-42. See also PRIA at 391 ("While the definitions of glider may vary from study to study (or even simulation to simulation), the agencies referenced the same dollar per pound of curb weight to develop costs for different glider definitions. In translating these values, the agencies took care to track units ($/kg vs. $/lb.) and the reference for percentage improvements (glider vs. curb weight).").

[952] In the Draft TAR, the agencies presented the cost estimates from mass reduction studies sponsored by both NHTSA and EPA. EPA presented the cost of mass reduction as function of vehicle curb weight. To harmonize the cost estimates with EPA, NHTSA also presented the cost of mass reduction as a function of vehicle curb weight.

[953] NHTSA-2018-0067-11943.

[954] NHTSA-2018-0067-12098.

(1) Studies Used to Develop Mass Reduction Cost Curves

The agencies described in the PRIA that since the 2012 final rule, both agencies conducted lightweighting studies to assess the technical feasibility and cost of mass reduction.[955] The agencies also stayed apprised of studies performed by other agencies, manufacturers, and industry trade associations, and reviewed them in development of lightweighting assumptions used in the NPRM and final rule analysis.[956] Among the several lightweighting studies, the agencies used NHTSA's passenger car lightweighting study, based on a MY 2011 Honda Accord, and NHTSA's full-size pickup truck lightweighting study, based on a MY 2014 Chevrolet Silverado, to derive the cost estimates to achieve different levels of mass reduction for the NPRM and final rule.

The agencies described that the decision to rely on those studies included that those studies considered materials, manufacturing, platform-sharing, functional attribute, performance, and noise-vibration- and harshness (NVH), among other constraints pertaining to cost, effectiveness, and safety considerations, in addition to that these vehicles were a reasonable representation of the baseline vehicles in the MY 2016 compliance simulation.[957] Specifically in regards to safety, the agencies described a preference to use studies that considered small overlap impact tests conducted by the Insurance Institute for Highway Safety (IIHS) and not all studies took that test into account. In regards to maintaining vehicle functionality, the agencies described that the NHTSA pickup truck study accounted for vehicle functional performance for attributes including towing, noise and vibration, and gradeability, in addition to considering platform sharing constraints.

In contrast, the agencies explained that the other studies often did not consider many important factors, or those studies made unrealistic assumptions about key vehicle systems through secondary downsizing, resulting in unrealistically low costs. Specifically, the agencies referenced EPA's past analysis of a MY 2010 Toyota Venza as an example of a study that employed overly aggressive secondary mass reduction, which translated into cost savings for the initial 10% mass reduction.[958]

The agencies received several comments on the studies used to generate the mass reduction cost curves. Ford commented in support of the agencies' decision to exclude mass reduction studies that were misaligned with tear-down studies.[959] Ford cited the MY 2010 Toyota Venza Phase II study used to establish the mass reduction cost values used for the Draft TAR and Proposed Determination that suggested the first 7-10% of mass reduction could be accomplished with zero or reduced cost,[960] which Ford characterized as "a gross underestimation of industry investment and material costs associated with any weight reduction."

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[955] PRIA at 390.
[956] PRIA at 403.
[957] PRIA at 403.
[958] PRIA at 391.
[959] NHTSA-2018-0067-11928
[960] EPA-420-R-16-021; Proposed Determination Technical Support Document at 2-158, November 2016

ICCT commented that The National Academies of Science "specifically endorsed tear-down studies as the most appropriate way to get at vehicle technology costs, [as those] studies are typically more accurate and far more transparent than the older method of surveying manufacturers, and such whole-vehicle studies are key to capturing holistic vehicle level mass-reduction technology costs." ICCT noted that there are many peer-reviewed tear-down studies that demonstrate that at least 20 percent mass reduction is available for adoption across vehicle classes by 2025, including studies by EDAG, FEV, Ford, and Lotus Engineering; however, ICCT alleged that the agencies "have either incorrectly interpreted or invalidly nullified the most relevant detailed engineering teardown studies on mass-reduction technology." ICCT noted that the agencies were "well aware" of these studies, as they were performed by CARB in conjunction with the agencies, however, ICCT alleged that the agencies "reinterpreted the results of the main study relied upon in the TAR in order to inflate costs," and that the "technical assessment by the agencies has a clear technical bias towards reducing CAFE and [CO_2] standards." ICCT concluded that "[e]xcluding these studies amounted to intentionally disregarding the most pertinent and rigorous engineering studies that are applicable to the rulemaking timeframe."

ICCT recommended the agencies adjust their technology cost inputs to reflect the "best-available technology studies." ICCT stated that the correct cost assumption from these studies is that "a 5-10% mass reduction by 2025 reduces vehicle cost, and the auto industry will cost-effectively deploy at least 15% vehicle curb mass reduction in the 2025 timeframe at near zero net cost (and consistently less than $500)."

CARB asserted that the agencies inflated the costs of mass reduction in the NPRM analysis by only considering NHTSA-sponsored studies and improperly excluding the effects of secondary mass reduction as documented in those studies.[961] CARB provided a table of studies that largely mirrored the tables of studies the agencies considered in the Draft TAR and PRIA,[962] and also included the associated mass reduction costs in $/kg included in each study, noting that for all excluded studies cited in the table, all mass reduction costs were substantially lower than the values used in the agencies' analysis.[963] Similarly, UCS commented that while the PRIA did state that additional studies "often did not consider many important factors or…made unrealistic assumptions about key vehicle systems," the agencies did not specifically identify the factors and assumptions that merited disregarding those studies, which were included previously in agency analysis as part of the record when deriving previous estimates for the costs of mass reduction.[964]

The agencies agree with ICCT that peer-reviewed tear-down studies present an appropriate method to capture holistic vehicle-level mass reduction technology costs. The agencies also agree with ICCT that the agencies were well aware of studies conducted by EDAG, FEV, Ford, and Lotus Engineering; in fact, the agencies presented a table listing several of those studies in the PRIA with the qualification that those studies were reviewed in developing lightweight assumptions for the analysis, but those studies did not consider important factors, or

[961] NHTSA-2018-0067-11873
[962] Draft TAR at 5-168; PRIA at 404-05.
[963] NHTSA-2018-0067-11873
[964] NHTSA-2018-0067-12039.

those studies made unrealistic assumptions about key vehicle systems through secondary downsizing, resulting in unrealistically low costs.

The agencies also agree with UCS' comment that we could have been more specific about identifying the factors and assumptions that merited disregarding studies that were previously included as part of the record when deriving previous estimates for the costs of mass reduction. The following discussion briefly summarizes the record since the Draft TAR and differences between NHTSA's and other lightweighting studies' approach to factors listed in the PRIA. Important for this discussion is an understanding of primary versus secondary mass reduction; as described above, when there is sufficient primary mass reduction, other components that are designed based on the mass of primary components may be redesigned and have lower mass. Recall the braking system example used throughout this section; mass reduction in the braking system is secondary mass reduction because it requires primary mass reduction before it can be incorporated. If the mass of primary components is reduced sufficiently, the resulting lighter weight vehicle could maintain braking performance, attributes, and safety with a lighter weight brake system.

Several studies were referenced in the Draft TAR that either used tear-down analyses and computer-aided engineering (CAE) to produce a future engineered lightweight vehicle, or considered future technologies and processes for lightweighting vehicle components.[965]

EPA developed cost curves for cars and CUVs based on the MY 2010 Toyota Venza study, and pickup truck cost curves based on the MY 2011 Chevrolet Silverado study.[966] The other studies were considered by EPA, but not used to develop the Draft TAR, Proposed Determination and Final Determination cost curves. In brief, EPA described that the Toyota Venza Phase I was a mass reduction opportunity study only, and the Phase II study was a holistic vehicle study that examined nearly every component in the vehicle for mass reduction potential and calculated a related cost and mass saved for each. For the cost curve, EPA applied the individual components in sequence from largest cost per kilogram savings to largest cost per kilogram increase. For example, the cost curve for the Draft TAR and Proposed Determination applied engine downsizing and transmission system mass reduction first, and before lightweighting the body, chassis, doors and other components.[967] EPA stated this methodology was chosen based on the understanding that OEMs will choose the cost saving technologies first and that some cost mass reduction technologies will be paid for by the cost save mass reduction technologies, citing a 2016 publication by CAR and a GM presentation that stated over $2,000,000,000 was saved in material costs through various lightweighting approaches.[968]

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[965] Draft TAR at 5-158 through 5-197.
[966] Draft TAR at 5-367.
[967] EPA-420-R-16-021: Proposed Determination Technical Support Document at 2-161 and 2-162
[968] Draft TAR at 5-172 (citing "Identifying Real world Barriers to Implementing Lightweighting Technologies and Challenges in Estimating the Increase in Costs," Center for Automotive Research, Jay Baron, PhD, January 2016 http://www.cargroup.org/?module=Publications&event=View&pubID=128.; General Motors, "General Motors 2015 Global Business Conference," Presentation, October 1, 2015, Slides 43-45 in document, https://www.gm.com/content/dam/gm/events/docs/5194074-596155-ChartSet-10-1-2015.).

The NHTSA cost curves were developed by rearranging the lightweighted components from the MY 2011 Honda Accord and MY 2014 Chevrolet Silverado studies based on cost effectiveness, assuming the vehicle body, chassis, interior, and other primary components were lightweighted first, followed then by lightweighting powertrain components and other secondary systems.[969] The cost curves based on the NHTSA studies reflect that, returning to this example, secondary mass reduction for the brake system is only applied after there has been sufficient primary mass reduction to allow the smaller brake system to provide safe braking performance and to maintain mechanical functionality.[970]

~~The EPA and NHTSA studies took fundamentally different approaches to accounting for the costs of mass reduction technology, and accordingly, EPA needed to translate the cost curves from the NHTSA studies to use a similar methodology as the cost curves from the EPA studies.[971] To "normalize" the NHTSA studies with the EPA's studies, EPA listed components identified for lightweighting in the NHTSA studies and reorganized those components from the lowest cost to highest cost along with associated mass reduction per the "whole vehicle" approach mentioned above, distributed mass savings from secondary mass reduction to all points along the cost curve, and included the mass saved from engine downsizing without taking into consideration the cost of added engine technology. This resulted in lower cost secondary mass reduction opportunities being considered before primary mass reduction opportunities, which in turn resulted in artificially low $/kg costs for mass reduction.~~

Commented [A257]: DELETE: This is not an accurate characterization of EPA's approach, and in any case is not necessary for supporting the technical analysis used for this FRM.

For the NPRM and final rule, the agencies simply used the original ordered list of components from the MY 2011 Honda Accord study and MY 2014 Chevrolet Silverado study, arranged sequentially for cost effectiveness based on primary then secondary mass reduction opportunities, to generate the cost curves for passenger cars and light trucks. Accordingly, the agencies did not "reinterpret" the results of studies used in the Draft TAR in the NPRM, as ICCT alleged, but rather appropriately represented how primary and secondary mass reduction opportunities are implemented in the real world (to the extent that ICCT is referring to the translation of the study costs to the NPRM glider weight assumptions, that is discussed in [Section How the Cost Curves Are Implemented in the CAFE Model], below). To maintain utility and performance in the real world, primary components must be lightweighted first before the engine and transmission can be resized. Moreover, as described in the Draft TAR, NHTSA's mass reduction studies did not "improperly exclude" the effects of mass reduction, rather those effects were appropriately accounted for after primary components achieved certain levels of mass reduction. As discussed in [Section Performance Neutrality], this approach aligned with the NAS approach to consider powertrain downsizing only after the vehicle structural components achieved 10 percent mass reduction.

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[969] Draft TAR at 5-421 ("The powertrain components which include engine, transmission, and fuel systems such as fuel filler pipe, fuel tank, fuel pump, etc., exhaust systems and cooling systems were not considered for application of primary mass reduction but benefits of secondary mass reduction were accounted for. These powertrain components are assumed to be downsized only after the primary vehicle structural components (Body-In-White) achieve certain level of mass reduction.").

[970] Draft TAR at 5-422.

~~[971] Draft TAR at 5-369.~~

OEMs have also disagreed with the conclusion that mass reduction could come at a cost savings. For instance, Ford characterized the Toyota Venza studies, which concluded the first 7-10% of mass reduction could come at a negative cost as "a gross underestimation of industry investment and material costs associated with any weight reduction." The agencies believe that the approach to secondary mass reduction followed in the NHTSA passenger car and pickup truck lightweighting studies appropriately incorporated both the costs and real-world constraints associated with employing primary and secondary mass reduction technologies.

Aside from the differences in how studies treated secondary mass reduction, the agencies opted not to use, or could not use, other studies either previously considered in the rulemaking record or mentioned by commenters for several reasons:

Studies were not comprehensive, and therefore could not be used to develop a comprehensive cost curve: Some studies narrowly assessed lightweighting of a portion of vehicle, such as the body in white subsystem, or as stated in the PRIA,[972] were limited to material substitution of the vehicle components, such as replacing steel with aluminum or replacing mild steel with AHSS or replacing mild steel with CFRP in selective components. Factors important to vehicle functionality, like material joining techniques and the feasibility of manufacturing processes or necessary retooling requirements were not considered, and therefore could not be used to develop a comprehensive cost curve representative of the costs required to reduce mass in a vehicle[973].

Cost curves were not developed or no cost analysis was performed: For the CARB Holistic Vehicle Mass Reduction/Cost Study, a cost curve was not developed, and the resulting cost per kilogram data points were point estimates. The calculated cost per kilogram was used as one data point of several to indicate the direction for mass reduction beyond EPA's original passenger car/CUV curve.[974] Or, as in the case of the DOE/Ford/Magna Multi Material Lightweight Vehicle (MMLV) project, no cost analysis was performed for the initial project, and later projects concluded that the demonstrated mass reduction was only possible "if carbon fiber composite materials and manufacturing processes are available and if customers will accept a reduction in vehicle features and content."[975]

Engineered vehicles did not meet functional design or manufacturing requirements: As noted in the update to EPA's Light-Duty Vehicle Mass Reduction and Cost Analysis for the Toyota Venza, the Phase I engineered Venza did not meet the design target of no expected NVH degradation.[976] The Phase II (high Development) study assumed significant cost savings from

[972] PRIA at 391.
[973] An Assessment of Mass Reduction Opportunities for a 2017-2020 Model Year Vehicle Program, March 2010, Lotus Engineering at Page 6
[974] Draft TAR at 5-185.
[975] Draft TAR at 5-194.
[976] Light-Duty Vehicle Mass Reduction and Cost Analysis – Midsize Crossover Utility Vehicle, EPA-420-R-12-026 (August 2012).

reduced parts manufacturing, but did not appropriately explain the methodology used to conclude that the part count reduction was feasible.[977]

In addition, the agencies qualified in the PRIA a preference to use studies that considered the small overlap impact test conducted by IIHS, and not all studies took that test into account.[978] NHTSA's "Update to Future Midsize Lightweight Vehicle Findings in Response to Manufacturer Review and IIHS Small-Overlap Testing" based on the MY 2011 Honda Accord presented results incorporating suggestions from Honda regarding NVH and durability, and updating the engineered vehicle to achieve a "good" rating in seven crash safety tests.[979] EPA studies also accounted for IIHS small overlap test through an ad hoc estimate of mass and cost, unlike the NHTSA update, which explicitly modeled to account for NVH performance and to comply with the IIHS small overlap test.

The agencies continue to believe that the MY 2011 Honda Accord and MY 2014 Chevrolet Silverado lightweighting studies are the best studies upon which to estimate the costs of mass reduction in the rulemaking timeframe.

(2) How the Cost Curves Are Applied in the Model

Commenters also submitted comments on how the cost curves were applied in the model, including that the studies the agencies relied upon to generate cost curves, discussed above, did not support the 50 percent glider share assumption used in the NPRM, and the agencies did not correctly scale the costs to match the glider share assumption.

UCS commented that the agencies based the costs for mass reduction on glider weight reduction, however, the need for more expensive materials and more advanced engineering and design strategies only results from the need for greater levels of absolute mass reduction on the vehicle.[980] UCS stated that the cost curves had effectively been derived from the assumption of reductions as great as 16.8 percent reduction in curb weight in the case of the Silverado (Singh et al. 2018) and as great as 18 percent reduction in curb weight in the case of the Honda Accord (Singh et al. 2016), but applied to curb weight reductions approximately two-thirds that magnitude. UCS stated that approach was "completely invalid and significantly overstates the costs for mass reduction." UCS also commented that the agencies incorrectly scaled the cost curves based on the agencies' mass reduction studies, which refer to direct manufacturing costs as a function of vehicle curb weight, not just glider weight. UCS stated this incorrectly yielded the same costs for two-thirds the amount of mass reduction.

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[977] See, Peer Review of Demonstrating the Safety and Crashworthiness of a 2020 Model-Year, Mass-Reduced Crossover Vehicle (Lotus Phase 2 Report), EPA-420-R-12-028 (September 2012).
[978] PRIA at 391.
[979] Singh, H., Kan, C-D., Marzougui, D., & Quong, S. (2016, February). Update to future midsize lightweight vehicle findings in response to manufacturer review and IIHS small-overlap testing (Report No. DOT HS 812 237). Washington, DC: National Highway Traffic Safety Administration.
[980] NHTSA-2018-0067-12039.

CARB similarly commented that the mass reduction costs assigned to both passenger cars and light trucks in the CAFE model were inappropriately inflated based on incorrect scaling from the glider share assumptions used in the Honda Accord and Chevy Silverado studies to the NPRM glider share value.[981] CARB analyzed two tables in the PRIA that showed the agencies' translation of cost numbers derived from the two studies to the cost numbers used in the CAFE model, and asserted that the agencies improperly used costs from the upper end of the mass reduction range rather than the midpoint of the range, leading to cost overestimation.

Similarly, HDS commented that the PRIA passenger car cost curves used data that were not in agreement with the study that they were based upon, noting that the Honda Accord study showed the glider accounting for 78% of curb weight, and this limited absolute weight reduction.[982] HDS noted that the truck weight reduction cost data were closer to those cited in the Chevy Silverado teardown study, although the glider share for that study was also 73.6% of vehicle curb weight.

HDS also commented that although the agencies relied on the same Honda Accord study that was used in the Draft TAR, "the costs have been changed significantly [from the Draft TAR] for unexplained reasons."[983] HDS stated that the PRIA showed average costs for mass reduction, whereas earlier studies showed the cost increment for each 5% mass reduction, noting that with increasing incremental cost with increased mass reduction, average cost will always be lower than incremental cost. HDS claimed that it was "unusual" for the Draft TAR incremental costs to decrease between 11% and 19% mass reduction but increase elsewhere, but also noted the unexplained increase in cost, specifically a $536 cost for 175kg weight reduction, shown in the PRIA.

HDS also compared manufacturing costs from the Draft TAR to the PRIA analysis, noting that the direct manufacturing cost was found to be negative (i.e., a cost saving) in the Draft TAR analysis for mass reduction up to 15 percent,, but EPA assumed the indirect costs were positive so that the total cost was a sum of positive and negative costs—meaning the total cost could be positive or negative. In contrast, HDS noted there were no negative costs in the cost curves used for the PRIA analysis, resulting in a very large differential between the costs of mass reduction, with the 2018 average cost being higher than even the 2016 marginal costs.

Three notable changes from the NHTSA Draft TAR to NPRM and final rule analysis impacted how the cost curves for mass reduction are applied in the CAFE Model.

First, the Draft TAR considered mass reduction in the glider and powertrain together, and calculated the percentage mass reduction on a vehicle curb weight basis. In the Draft TAR, only one engine and transmission combination were considered to account for the mass change associated with downsizing the engine, and the cost estimates for mass reduction for this *one* powertrain combination was applied to *all* powertrain combinations. This approach did not account for the mass changes associated with the application of powertrain technologies (engine,

[981] NHTSA-2018-0067-11873.
[982] NHTSA-2018-0067-11985.
[983] NHTSA-2018-0067-11985.

transmission and electrification) technologies, and did not account for the corresponding change in glider mass needed to offset the powertrain mass change and to achieve the specified curb weight mass reduction level. This approach did not reflect the real world, where there are many vehicles with different body styles and powertrain combinations, and therefore did not account for differences in mass for different engines, transmissions, or electrification.

Accordingly, for the NPRM and final rule, the cost of mass reduction was calculated on a glider weight basis so that the weight of each powertrain configuration could be directly and separately accounted for. This approach provides the true cost of mass reduction without conflating the mass change and costs associated with downsizing a powertrain or adding additional advanced powertrain technologies. Hence, the mass reduction costs in the NPRM reflect the cost of mass reduction in the glider and do not include the mass reduction associated with engine downsizing, and therefore appear to be higher than the cost estimates in the Draft TAR.

Second, the glider share of curb weight changes from the Draft TAR to NPRM and from the NPRM to the final rule analysis also affected the absolute amount of curb weight reduction that was applied, and therefore for cost per pound for the mass reduction changes with the change in the glider share. The cost for removing 20 percent of the glider weight when the glider represents 75% of a vehicle's curb weight is not the same as the cost for removing 20 percent of the glider weight when the glider represents 50% of the vehicle's curb weight. For example, the glider share of 79 percent of a 3,000-pound curb weight vehicle is 2,370 pounds, while the glider share of 50 percent of a 3,000-pound curb weight vehicle is 1,500 pounds, and the glider share of 71 percent of a 3,000-pound curb weight vehicle is 2,130 pounds. The mass change associated with 20 percent mass reduction is 474 pounds for 79 percent glider share (=[3,000 pounds x 79% x 20%]), 300 pounds for 50 percent glider share (=[3,000 pounds x 50% x 20%]), and 426 pounds for 71 percent glider share (=[3,000 pounds x 71% x 20%]). The mass reduction cost studies show that the cost for mass reduction varies with the amount of mass reduction. Therefore, for a fixed glider mass reduction percentage, different glider share assumptions will have different costs.

To further illustrate, Table VI-66Table VI-66 below shows the associated curb weight percentage mass reduction and the associated average cost per pound for different glider weight assumptions for each glider mass reduction technology level used in the final rule analysis. For reference, the costs from the passenger car light weighting study are presented.[984] These costs were the basis for deriving the costs for each mass reduction technology level in the Draft TAR, NPRM, and final rule analyses, using the unique glider share values for each of those analyses. In the light weighting study, NHTSA applied the mass reduction technologies identified for the exemplar vehicle on other vehicle(s) and vehicle types to understand the level of mass reduction that could be achieved. In the case of passenger cars, the maximum level of mass reduction was around 15% of the vehicle curb weight if all the mass reduction technologies are applied. In other words, achieving mass reduction greater than 10% of the curb weight for passenger cars

[984] Table 6-39 in PRIA

will require extensive use of advanced materials such as high strength aluminum and carbon fiber composite material.

Table VI-66 - Mass Reduction RPE Costs per Pound for MY 2017 as a Function of Percentage Curb Weight Reduction for 79%, 50%, and 71% Glider Shares for Passenger Car (2018$)

	Final Rule 71% Glider Weight		NPRM 50% Glider Weight		Draft TAR 75% Glider Weight		NHTSA Light Weighting Study 79% Glider Weight	
MR Level	Curb Weight Reduction	RPE	Curb Weight Reduction	RPE	Curb Weight Reduction	RPE	Curb Weight Reduction	RPE
MR0	0.00%	$0.00	0.00%	$0.00	0.00%	$0.00	0.00%	$0.00
MR1	3.55%	$0.51	2.50%	$0.44	3.75%	$0.57	3.94%	$0.60
MR2	5.33%	$0.95	3.80%	$0.53	5.63%	$1.06	5.90%	$1.14
MR3	7.10%	$1.31	5.00%	$0.81	7.50%	$1.44	7.87%	$1.50
MR4	10.65%	$1.87	7.50%	$1.50	11.25%	$2.08	11.81%	$2.18
MR5	14.20%	$7.54	10.00%	$2.73	15.00%	$9.33	15.74%	$11.00
MR6	20.00%	$17.74						

Table VI-9 - Mass Reduction RPE Costs per Pound for MY 2017 as a Function of Percentage Curb Weight Reduction for 79%, 50%, and 71% Glider Shares for Light Trucks (2018$)

MR Level	Final Rule 71% Glider Weight		NPRM 50% Glider Weight		Draft TAR 75% Glider Weight		NHTSA Light Weighting Study 79% Glider Weight	
	Curb Weight Reduction	RPE	Curb Weight Reduction	RPE	Curb Weight Reduction	RPE	Curb Weight Reduction	RPE
MR0	0%	$0.00	0.00%	$0.00	0.00%	$0.00	0.00%	$0.00
MR1	4%	$0.33	2.50%	$0.26	3.75%	$0.37	3.68%	$0.36
MR2	5%	$0.77	3.80%	$0.36	5.63%	$0.89	5.52%	$0.85
MR3	7%	$1.34	5.00%	$0.62	7.50%	$1.51	7.36%	$1.48
MR4	11%	$2.00	7.50%	$1.43	11.25%	$2.69	11.04%	$2.19
MR5	14%	$9.75	10.00%	$2.54	15.00%	$11.36	14.72%	$11.00
MR6	20%	$17.79						

Finally, as explained earlier, to determine the mass reduction technology levels for the NPRM 2016 analysis fleet, a distribution of the residuals from the regression using 50 percent glider weight generally showed a greater percentage of vehicles achieving higher levels of mass reduction. With this high level of mass reduction already achieved, the opportunities for further mass reduction would be limited and have higher costs. For the final rule, since we updated the glider share to 71 percent of the vehicle

curb weight, the distribution of residuals from the regression shifted some vehicles to lower baseline mass reduction technology levels, providing more opportunity for further mass reduction, on average. Even as some of the vehicles start further up on the mass reduction cost curve due to higher levels of mass reduction technology (MR3, MR4) already present in the vehicles, there are additional opportunities for further mass reduction to achieve MR5 and above.

Table I-8 and Table I-9 show that for the final rule, cost estimates with the 71 percent glider share come closer to the cost estimates used in Draft TAR, which assumed a 79 percent glider share.

(3) Secondary Mass Reduction Costs

As discussed above, the agencies changed the cost of mass reduction calculation from a curb weight basis in the Draft TAR to a glider weight basis in the NPRM.[985] This change allowed us to estimate the cost of mass reduction independently of the cost associated with downsized advanced engines and advanced transmissions, as the cost of downsized advanced engines and transmissions are accounted for separately in the CAFE model.

The MY 2011 Honda Accord and MY 2014 Chevy Silverado studies used to develop the NPRM and final rule cost curves for mass reduction technologies include some non-powertrain secondary mass reduction technologies such as brakes and wheels. The agencies presented the list of mass reduction technologies in NPRM.[986] Following the publication of NHTSA's light weighting studies, peer reviewers and manufacturers commented that many components such as drive axles, engine cradles, and radiator engine support that are considered to be non-powertrain secondary mass reduction opportunities cannot be downsized as the same components are used across many vehicles with different powertrain options. As a result, the agencies did not consider these components for either primary or secondary mass reduction opportunities.

Commenters faulted the agencies for a perceived lack of accounting for the cost decreases from secondary mass reduction. ICCT commented although the agencies relied on the Honda Accord study, which considered cost savings from downsizing the powertrain, in the NPRM only glider weight reduction was ever considered without the cost-offsetting engine downsizing.[987] ICCT stated that this omission had two effects, first that accounting for associated powertrain weight reductions would have allowed for more mass reduction, thus allowing for greater efficiency benefits at a lower cost, and second, that vehicle performance was erroneously improved, contrary to the agencies' assertion that the analysis assumed a level of performance neutrality. ICCT concluded that it was unclear if and how costs were reduced for powertrain downsizing, as well as the precise changes to fuel efficiency.

[985] In the Draft TAR, the agencies presented the cost estimates from mass reduction studies sponsored by both NHTSA and EPA. EPA presented the cost of mass reduction as function of vehicle curb weight. To harmonize the cost estimates with EPA, NHTSA also presented the cost of mass reduction as a function of vehicle curb weight.
[986] Table 6-37 and Table 6-40 in PRIA.
[987] NHTSA-2018-0067-11741.

CARB faulted the agencies for uot including secondary mass reductiou in the NPRM analysis, and stated that by failing to account for secondary mass reduction as was done in the Draft TAR, the agencies inflated the costs for mass reduction as well as the amount of mass reduction that is feasible and cost-effective leading to an overestimate in the technology costs needed to meet the existing standards.

The agencies note that the cost curves used for the NPRM and this final rule do in fact include secondary mass reduction. The cost curves reflect secondary mass reduction applied when there is sufficient primary mass reduction to implement secondary mass reduction without degrading function and safety. Specifically, the NHTSA studies, upon which the cost curves were built, first generated costs for lightweighting the vehicle body, chassis, interior, and other primary components, and then calculated costs for lightweighting secondary components. Accordingly, the cost curves reflect that, for example, secondary mass reduction for the brake system is only applied after there has been sufficient primary mass reduction to allow the smaller brake system to provide safe braking performance and to maintain mechanical functionality.

In addition, CARB stated that the 2011 Honda Accord and the 2014 Chevrolet Silverado studies had "markedly" lower costs than the proposal when secondary mass reduction is included. Again, the agencies believe these comments resulted from a lack of understanding about how the analysis considers primary and secondary mass reduction, even though we explicitly stated how costs are acconnted for separately in the NPRM and PRIA.[988] Also, as discussed above, engine mass reduction enabled by mass reduction in the glider is accounted for separately and therefore not included as part of glider mass reduction technology, as doing so would result in double counting the impacts.

(4) Summary of Final Rule Mass Reduction Costs

For the final rule, the agencies continue to use multiple mass reduction technology levels and costs based on the lightweighting studies that were presented in PRIA.[989] Since the agencies have changed the glider share of curb weight assumption from 50 percent in NPRM to 71 percent in the final rule, the mass reduction costs reflect the updated glider share. Table VI-67Table VI-67 and Table VI-68Table VI-68 show mass reduction costs used in the CAFE model for passeuger car and light trucks.

Table VI-67 - Mass Reduction Costs in CAFE model for Passenger Cars in Final Rule

[Table Forthcoming]

Table VI-68 - Mass Reduction Costs in CAFE model for Light Trucks in Final Rule

[Table Forthcoming]

[988] [cite forthcoming]
[989] Table 6-37 and 6-40 in PRIA.

5. Aerodynamics

The energy required to overcome aerodynamic drag accounts for a significant portion of the energy consumed by a vehicle, and can become the dominant factor for a vehicle's energy consumption at high speeds. Reducing aerodynamic drag can, therefore, be an effective way to reduce fuel consumption and emissions.

Aerodynamic drag is proportional to the frontal area (A) of the vehicle and coefficient of drag (C_d), such that aerodynamic performance is often expressed as the product of the two values, C_dA, which is also known as the drag area of a vehicle. The coefficient of drag (C_d) is a dimensionless value that essentially represents the aerodynamic efficiency of the vehicle shape. The frontal area (A) is the cross-sectional area of the vehicle as viewed from the front. It acts with the coefficient of drag as a sort of scaling factor, representing the relative size of the vehicle shape that the coefficient of drag describes. The force imposed by aerodynamic drag increases with the square of vehicle velocity, accounting for the largest contribution to road loads' higher speeds.

Aerodynamic drag reduction can be achieved via two approaches, either by reducing the drag coefficient or reducing vehicle frontal area, with two different categories of technologies, passive and active aerodynamic technologies. Passive aerodynamics refers to aerodynamic attributes that are inherent to the shape and size of the vehicle, including any components of a fixed nature. Active aerodynamics refers to technologies that variably deploy in response to driving conditions. These include technologies such as active grille shutters, active air dams, and active ride height adjustment. It is important to note that manufacturers may employ both passive and active aerodynamic technologies to achieve aerodynamic drag values.

The greatest opportunity for improving aerodynamic performance is during a vehicle redesign cycle when significant changes to the shape and size of the vehicle can be made. Incremental improvements may also be achieved during mid-cycle vehicle refresh using restyled exterior components and add-on devices. Some examples of potential technologies applied during mid-cycle refresh are restyled front and rear fascia, modified front air dams and rear valances, addition of rear deck lips and underbody panels, and low-drag exterior mirrors. While manufacturers may nudge the frontal area of the vehicle during redesigns, large changes in frontal area are typically not possible without impacting the utility and interior space of the vehicle. Similarly, manufacturers may improve C_d by changing the frontal shape of the vehicle or lowering the height of the vehicle, among other approaches, but the form drag of certain body styles and airflow needs for engine cooling often limit how much C_d may be improved.

During the vehicle development process, manufacturers use various tools such as Computational Fluid Dynamics (CFD), scaled clay models, and full size physical prototypes for wind tunnel testing and measurements to determine aerodynamic drag values and to evaluate alternate vehicle designs to improve those values.

The agencies presented a table in the PRIA showing aerodynamic drag improvements from individual technologies based on wind-tunnel testing for a study commissioned by

Transport Canada, which is reproduced in Table VI-69Table VI-69 below.[990] The individual technologies are present in many of the 2016 and 2017 vehicles in the fleet. Table VI-69Table VI-69shows the list of aerodynamic technologies and corresponding aero drag improvements.

Table VI-69 – Aerodynamic Technologies and Aero Drag Improvements

[Table Forthcoming]

As discussed in the PRIA and further below, the agencies made several notable changes for modeling aerodynamic improvement technologies from the Draft TAR to the NPRM. First, the agencies revised the aerodynamic improvements from two levels in the Draft TAR (10% and 20% improvement over the baseline) to four levels (5%, 10%, 15% and 20% aerodynamic drag improvement values over the baseline). This change provided the improved granularity to bin the vehicles with different aerodynamic improvements more appropriately. Next, the agencies assigned levels of aerodynamic technology to the MY 2016 fleet on a relative basis based on confidential business information submitted by the manufacturers, taking steps to verify information submitted by manufactures with other sources, and making changes particularly for vehicles that showed large improvements over baseline values. Third, the agencies limited the maximum level of aerodynamic improvements that certain body styles (pickup trucks, minivans) could achieve and limited the maximum level of improvements that cars and SUVs with more than 405 horsepower could achieve based on the agencies' assessment of industry comments. Finally, the agencies updated the cost for aerodynamic improvements based on the assessment of comments that the National Academy of Sciences (NAS) cost estimates used in the Draft TAR underestimated the cost for aerodynamic improvements.

Broadly, Ford commented in support of the approach to aerodynamic improvement modeling in the NPRM, stating that the rule recognized potential constraints like consumer needs and preferences regarding vehicle styling, vehicle utility, and interior space, by among other things, recognizing that the potential for aerodynamic drag differs among different vehicle body styles and vehicle classes.[991] Ford stated that these are major factors considered by customers when comparing competing vehicles, and the failure of a manufacturer to deliver in these areas can lead to the production of non-competitive, poor-selling vehicles.

On the other hand, ICCT claimed that the agencies greatly limited the availability of many load reduction technologies (i.e., mass reduction improvements, aerodynamic improvements, and rolling resistance improvements) by pushing very large amounts of these technologies into the 2016 model year baseline fleet, thereby making the technologies unavailable for use in future years.[992] ICCT commented that these improvements in the analysis fleet would ostensibly amount to massive efficiency improvements, however, these assumed changes were not substantiated as resulting in any test-cycle efficiency improvements in the

[990] Table 6-63 in PRIA.
[991] NHTSA-2018-0067-11928.
[992] NHTSA-2018-0067-11741 full comments.

model year 2016 fleet versus the 2015 fleet. ICCT concluded that the adjusted baseline had been developed and presented opaquely, apparently based primarily upon estimations from automaker-supplied data, without critical analysis, vetting, or sharing of the necessary data to substantiate the changes and real-world benefits by the agencies.

As discussed further in Section [Aero analysis fleet section] below, the agencies believe the updated analysis fleet aerodynamic technology level assignments in the NPRM analysis represent an improvement over the MY 2015 assignments in the Draft TAR, as the updated assignments are based on precise values, not estimated from road load coefficients, and have been corroborated by observed improvements on actual production vehicles. Accordingly, the agencies carried over the NPRM approach for determining the aerodynamic technology levels for the analysis fleet to the final rule.

a) Aerodynamics Drag Reduction Modeling in the CAFE Model

The agencies summarized in the PRIA that the Draft TAR aerodynamic improvement levels were binned into two groups, AERO1 and AERO2. However, market observations showed that many vehicles had aero improvements from 0% to 10%, and some vehicles showed improvements from 10% to 20%.[993] Based on industry feedback and market observations, the agencies revised the aerodynamic improvements from two levels in the Draft TAR (10% and 20% improvement over the baseline) to four levels (5%, 10%, 15% and 20% aerodynamic drag improvement values over the baseline). This revision provided the necessary granularity to bin the vehicles with different aerodynamic improvements appropriately. Table VI-70Table VI-70 shows aerodynamic improvement levels in the NPRM and final rule.

Table VI-70 – Aerodynamic Technology Levels in the NPRM and Final Rule

[Table Forthcoming]

ICCT commented that to model appropriately the baseline standards, the agencies would need to include increasing use of aerodynamic off-cycle technology credits across all companies through 2025. ICCT stated that it appeared that the agencies did not use EPA's engineering expertise or compliance data, where EPA would be able to advise better based on their certification data from the off-cycle program.

As discussed further in Section [AC and off-cycle], the NPRM analysis carried forward manufacturers' off-cycle fuel consumption improvement values (FCIVs) at MY 2016 levels unless an explicitly simulated off-cycle technology, like start-stop systems, was added to a vehicle in the simulation modeling. Specific to aerodynamic improvements, active grille shutters were assumed to be applied at the 20 percent aerodynamic improvement (AERO20) level. For the final rule analysis, based on the assessment of comments that the application of off-cycle technologies in the analysis was too conservative, the agencies agreed and increased each

[993] PRIA at 437.

manufacturers' application of off-cycle technologies so that 10 g/mi of technology was applied by 2023, using an extrapolated increase in levels in MYs 2017-2023 based on EPA compliance data.[994] This approach did not assume any specific mix of off-cycle technologies that would be used by manufacturers to achieve the 10 g/mi off-cycle improvement, because manufactures currently use a variety of technologies, and different manufacturers likely would implement unique combinations of technologies. It is expected that aerodynamic off-cycle technologies would be included in the mix of off-cycle technologies.

Table VI-71Table VI-71 and Table VI-72Table VI-72 show aerodynamic technologies that could be used to achieve 5%, 10%, 15% and 20% aero improvements in passenger cars, SUVs, and pickup trucks.[995] The agencies developed these potential combinations of technologies using aerodynamic data from [NRC of Canada] sponsored wind tunnel testing, extensive review of production vehicles utilizing these technologies, and industry comments. These technology combinations are intended to show a *potential* way for a manufacturer to achieve each aerodynamic improvement level; however, in the real world, manufacturers may implement different combinations of aerodynamic technologies to achieve a percentage improvement over their baseline vehicles.

Table VI-71 – Combinations of Technologies That Could Achieve Aerodynamic Improvements Used in the NPRM and Final Rule Analyses for Passenger Cars and SUVs

Aerodynamic Improvements for Passenger Cars and SUVs		
Aero Improvement Level	Components	Effectiveness (%)
AERO5	Front Styling	2.0%
	Roof Line raised at forward of B-pillar	0.5%
	Faster A pillar rake angle	0.5%
	Shorter C pillar	1.0%
	Low drag wheels	1.0%
AERO10	Rear Spoiler	1.0%
	Wheel Deflector / Air outlet inside wheel housing	1.0%
	Bumper Lip	1.0%
	Rear Diffuser	2.0%
AERO15	Underbody Cover Incl. Rear axle cladding)	3.0%
	Lowering ride height by 10mm	2.0%
AERO20	Active Grill Shutters	3.0%
	Extend Air dam	2.0%

[994] The 2018 EPA Automotive Trends Report, https://www.epa.gov/fuel-economy-trends/download-report-co2-and-fuel-economy-trends.
[995] Table 6-67 and Table 6-68 in PRIA.

Table VI-72 – Combinations of Technologies That Could Achieve Aerodynamic Improvements Used in the NPRM and Final Rule Analyses for Pickup Trucks

For Pickups		
Aero Improvements	Components	Effectiveness (%)
AERO5	Whole Body Styling (Shape Optimization)	15.0%
	Faster A pillar rake angle	0.5%
	Rear Spoiler	1.0%
	Wheel Deflector / Air outlet inside wheel housing	1.0%
	Bumper Lip	1.0%
AERO10	Rear Diffuser	2.0%
	Underbody Cover Incl. Rear axle cladding)	3.0%
AERO15	Active Grill Shutters	3.0%
	Extend Air dam	2.0%

b) Aerodynamic Drag Reduction Analysis Fleet Assignments

The agencies described in the PRIA that for the 2015 analysis fleet used in the Draft TAR, the agencies received C_d values for the MY 2015 vehicles' baseline assignments from manufacturers, or used estimated C_d values. In response, the industry commented that C_d values often varied by measurement approach and, therefore, it was important to account for differences in the methodologies used to estimate those values. For instance, aerodynamic drag coefficients for the same vehicle often vary significantly from wind-tunnel to wind-tunnel, complicating cross-comparison and cross-referencing.[996] The industry commented that, on average, the manufacturer-reported C_d values are nine percent lower than the values reported by USCAR.[997] For reference, USCAR follows the SAE J2881 test procedure. However, because C_d values are not required to be reported for compliance, manufacturers can and do choose different methods to estimate the C_d values. Therefore, the industry commented that assigning baseline aerodynamic improvement levels should not simply be comparing the lowest reported C_d value in a vehicle segment to other reported C_d values. The industry commented that such a comparison would not reflect the plausible amount of aerodynamic drag improvement that could be achieved. Accordingly, the industry suggested that the analysis should normalize manufacturer-reported C_d values using SAE J2881.

The commenters stated manufacturers have the option to use other methods (apart from coast down testing) to estimate the C_d values such as wind tunnel testing, cross referencing the C_d value from other vehicles with similar frontal design and aero technologies deployed. Since manufacturers do not have to specify the methodology used to estimate the C_d value, the agencies have limited capability to make accurate comparisons of the C_d value estimates from different testing methods. As a result, the agencies determined using average(s) of the fleet provide a

[996] PRIA at 435.
[997] Footnote in PRIA at 435: FCA Draft TAR comments. Docket ID: NHTSA-2016-0068-0082.

better estimate of C_d levels than using the lowest C_d value in the fleet to assign aerodynamic improvement levels. The agencies determined it is appropriate to continue to use the NPRM approach for the final rule.

The NPRM and final rule analysis used a relative performance approach to assign the current aerodynamic technology level to a vehicle. Different body styles offer different utility and have varying levels of baseline form drag. In addition, frontal area is a major factor in aerodynamic forces, and the frontal area varies by vehicle. This analysis considered both frontal area and body style as utility factors affecting aerodynamic forces; therefore, the analysis assumed all reduction in aerodynamic drag forces come from improvement in the C_d. Per the process outlined in NHTSA's section of the Draft TAR, the agencies computed an average C_d for each body style segment in the MY 2015 analysis fleet from drag coefficients published by manufacturers. By comparing the C_d among vehicles sharing body styles, this allowed the agencies to estimate the level of aerodynamic improvement present on specific vehicles.

While some small differences existed between the aggregate MY 2015 and MY 2016 data, the agencies retained the NHTSA-calculated MY 2015 average C_d as the baseline drag coefficient for nearly all body styles. For pickup trucks, the agencies assigned a baseline drag coefficient of 0.42, considering that a large portion of the pickups sold in MY 2015 already included aerodynamic features assumed for advanced levels of aero. The agencies harmonized the Autonomie simulation baselines with the analysis fleet assignment baselines to the fullest extent possible.[998]

The agencies assigned levels of aerodynamic technology to the MY 2016 fleet based on confidential business information submitted by manufacturers on aerodynamic drag coefficients, and from other information sources such as in product release information. The analysis referenced manufacturer-submitted data (if that data was supplied), and the agencies took industry comments to Draft TAR into account and closely reviewed the manufacturer-submitted C_d data. In the few cases that manufacturers did not submit C_d values as confidential business information, the agencies estimated the C_d based vehicle attributes, design, and aero technologies applied to that vehicle. The agencies noted that the C_d values reported by some manufacturers showed high levels of improvement relative to the previous model year or previous generation. In some cases, the agencies contacted the manufacturers to further discuss differences in C_d estimation methodologies. Where appropriate, the agencies adjusted MY 2016 fleet C_d values after consultation with the manufacturers and used these values to assign baseline technology levels for each vehicle in the NPRM CAFE model simulation.

The Alliance commented that the NPRM analysis fleet had more appropriately assigned aerodynamic technology levels, and the assignments were more accurate than the Draft TAR, where vehicles were generally considered to have little aerodynamic improvement technology, and the CAFE model would add aerodynamic improvement despite the fact that manufacturers had already made significant improvements and there was little opportunity remaining for more.

[998] Often, vehicles assigned to technology classes do not perfectly match up with simulated vehicles, but in most cases this analysis assumed the aerodynamic effects and other specifications were comparable and appropriate for use as proxies.

The Alliance concluded that the Draft TAR approach ultimately led the CAFE model to under-predict how much powertrain technology was required for compliance. The Alliance also commented that it is possible to estimate aerodynamic features of a vehicle using road load coefficients, but the process requires various assumptions and is not very accurate. The Alliance concluded that the agencies' use of CBI to assign initial aerodynamic improvement values is an accurate and practical solution to support correct baseline assignments. Ford commented that the use of actual data, like manufacturer confidential information or other sources, to characterize better the aerodynamic improvements already incorporated into the baseline fleet is a substantial improvement over previous analyses that either assumed no aero improvement due to insufficient data, or attempted to infer C_d from the road load coefficients.[999] Ford stated that attempting to infer C_d from road load coefficients is not sufficiently accurate for a vehicle-level determination since the aerodynamic component of the road load coefficients is inextricably confounded with tire, transmission, and other parasitic losses. As part of its comments that the proposed rule analysis recognized constraints like consumer needs and preferences regarding vehicle styling and utility, Ford stated that the baseline C_d for pickup trucks properly recognized that these vehicles already include many advanced-level aerodynamic technologies. Ford concluded that an accurate assessment of the current technological state of the baseline fleet is critical to ensuring that the benefits of technological improvements are not "double-counted" in the modeling.

On the other hand, ICCT commented that the agencies artificially limited the availability of aerodynamic technologies in the CAFE model in future years by assigning approximately three times as many aerodynamic technology packages in the 2016 analysis fleet as they did in the 2015 baseline fleet used in the Draft TAR.[1000] ICCT noted that the 2015 Draft TAR fleet had about 8 percent vehicles sold with one of the aerodynamic packages, whereas the NPRM's 2016 fleet had about 53 percent, and argued that the agencies did not justify the increase with data to show that automakers actually deployed the technology. ICCT pointed to the agencies' introduction of intermediate aerodynamic improvement steps as the justification for the change, which ICCT argued "redistributes the baseline fleet into more advanced aerodynamic levels without observing or verifying real-world aerodynamic improvements."

ICCT argued that if an improvement of this magnitude were true, it would be evident in fleet level miles-per-gallon and CO_2 levels (e.g., in EPA's *Trends* and *Manufacturer Performance* reports), but none of the quantifiable mpg or CO_2 benefits that would be associated with these additional aerodynamic improvements were reflected in any real-world evidence in the model year 2016 fleet.

ICCT stated that, to show the automakers deployed this level of aerodynamic improvements, the agencies needed to show data on how these improvements are evident in the fleet and delivering benefits. Specifically, ICCT stated that the agencies must share the basis for any aerodynamic calculation and exact estimated percent improvement (rather than binned percentage categories) for each vehicle make and model in the baseline and future modeled fleet, and their technical justification for each value, arguing that not doing so would obscure the

[999] NHTSA-2018-0067-11928.
[1000] NHTSA-2018-0067-11741 full comments.

agencies' methods. In addition, ICCT stated that the agencies must conduct two sensitivity analysis cases that assume that every baseline make and model is set to 0 percent aerodyuamic improvement and set to the previous baseline aerodynamic levels (i.e., from TAR) to demonstrate how much the agencies' decision to load up more baseline technology affects the compliance scenarios. ICCT concluded that because changes in aerodynamic improvement assumptions "are opaquely buried in the agencies' datafiles and unexplained," the agencies must issue a new regulatory analysis and allow an additional comment period for review of the methods and analysis.

ACEEE asserted, as part of its comments that the MY 2016 analysis fleet assignments appeared to contain errors, that the assignment of AERO10 for the MY 2016 Toyota Tundra pickup truck was in error.[1001] ACEEE stated that Tundra pickup trucks have had similar specs from MY 2011 to today, and the C_d for all Tundra models has been 0.37 or 0.38 for 2WD and 4WD, respectively, since MY 2011. ACEEE noted that this is higher than the AERO10 C_d cut off value of 0.355 for pickups, as shown in the 2016 Draft TAR and referenced in the PRIA.

As described above, the agencies assigned levels of aerodynamic technology to the NPRM MY 2016 analysis fleet on a relative basis based on confidential business information submitted by the manufacturers on aerodynamic drag coefficients and other information sources such as in product release information. In addition, based on the Draft TAR comments, the agencies verified wherever possible the information submitted by manufactures with other sources (product release information and cross referencing with vehicles with similar design features and aero technologies), and made changes particularly for vehicles which showed large improvements over baseline values. Figure 6-175 in PRIA presented the distribution of different levels of aerodynamic drag improvements in MY 2016 vehicle fleet in NPRM relative to MY 2015 vehicle fleet used in Draft TAR. The distribution shows that 46 percent of the MY 2016 vehicle fleet was assigned AERO0 (0 percent improvement), 31 percent of the fleet was assigned AERO5 (5% improvement), and 15 percent of the vehicle fleet was assigned AERO10 (10 percent improvement). This distribution clearly shows that there is substantial opportunity for additional aerodynamic drag improvements in the vehicle fleet.

Regarding comments by ACEEE on Toyota Tundra pickup trucks, as just stated, the agencies used manufacturer submitted information and other available information to assign aerodynamic technology levels and the agencies applied the same process for all of the manufacturers for the NPRM and for the final rule. The agencies did assign AERO10 for some Toyota Tundra pickups, but not for all as asserted by ACEEE. Some of the Toyota Tundra pickups with 2WD and short bed and crew cab or double cab were assigned AERO5 and other configurations were assigned AER10.[1002] For reference, the baseline C_d value used in the NPRM for pickups is 0.395; a 5 percent improvement in Cd value is 0.375 and 10 percent improvement in Cd value is 0.355. The agencies considered the ACEEE comment and available information

[1001] NHTSA-2018-0067-12122, at 6.
[1002] The variations could be from coast down testing with different powertrains and with different pickup bed length and crew cab configurations.

and determined the aerodynamic assignments for the Toyota Tundra were reasonable for the final rule analysis.

Table VI-73Table VI-73 below shows the percentage aerodynamic drag improvement assigned to the MY 2015 (Draft TAR), MY 2016 (NPRM) and MY 2017 (final rule) analysis fleets. It is clear from this table that there is natural progression of aero technologies being adopted and the vast majority of the MY 2017 vehicle fleet is at or below AERO10 (81percent).

Table VI-73 – Aerodynamic Technology Assignments in MY 2017, MY 2016 and MY 2015 Vehicle Fleet

AERO Levels	Final Rule	NPRM	Draft TAR
AERO0	41%	46%	92%
AERO5	40%	31%	
AERO10	13%	15%	6%
AERO15	5%	7%	
AERO20	1%	1%	2%

Moreover, notable aerodynamic improvements have actually been observed on production vehicles. As described in PRIA, EPA observed 76 vehicles at the 2015 North American International Auto Show in Detroit (2015 NAIAS).[1003] EPA's observations showed that manufacturers have widely deployed both active and passive aerodynamic drag reduction technologies with significant opportunity remaining to apply aero technologies further in more optimized fashion as vehicles enter redesign cycles in the future.[1004] Although EPA did not identify the aerodynamic drag coefficient values for these vehicles, Figure 6-167 in PRIA showed the distribution of some aero technologies identified by EPA during this informal survey.

The survey showed that wheel dams and underbody panels are the most widely used aero technologies, followed by front bumper air dams and active grill shutters. Since this survey, many pickup trucks and passenger cars have active grill shutters installed to improve aerodynamic drag, and to get off-cycle credit. Table 6-67 in PRIA shows the "active grill shutter" by itself will improve aerodynamic drag reduction improvement by 3 percent. Combined with other aero technologies, this can improve the aerodynamic drag reduction values significantly in pickup trucks and SUVs. As a result, there has been overall fleet wide aerodynamic drag reduction improvement; however, the above Table VI-73Table VI-73 shows that only 19 percent (13 percent from AERO10, 5 percent from AERO15 and 1 percent from AERO20) of the MY 2017 vehicle fleet have aerodynamic drag reduction improvement greater than 10 percent. This shows that there is significant opportunity for the vehicle fleet to improve aero technologies by MY 2025.

[1003] PRIA at 432. *See also* Docket No. EPA-HQ-OAR-2015-0827.
[1004] Draft TAR 5.3.4.4 Aerodynamics: Data and Assumptions for this Assessment.

The agencies also described examples of how production vehicles in different technology classes improved aerodynamic drag reduction values relative to their previous generation model since the 2012 final rule.[1005] Regarding ICCT's comment that, if an improvement in baseline aerodynamic improvements were true, it would be evident, as seen through real-world evidence in the model year 2016 fleet. For example, MY 2015 Ford F150 has the passive and active aerodynamic technologies as shown in Table VI-74Table VI-74.

The air curtain technology in the MY 2015 F150 guides the air flow across the front wheels to reduce wind turbulence.[1006] For reference, the wind tunnel testing by NRC of the MY 2015 Ford F150 showed a drag coefficient value of 0.37 while the coast down testing by EPA pegged the drag coefficient value between 0.35 to 0.40 depending on the type of powertrain, cab and cargo box combination. The prior generation F150 was released in 2008 as a MY 2009 and this vehicle had very few aerodynamic technologies applied. The agencies do not have the MY 2009 Cd value to estimate the percentage improvement. Since, F150 also included significant light weighting and powertrain improvements including a down sized turbocharged engine, the effectiveness improvement attributable to aerodynamic technologies is uncertain.

Table VI-74 – Aerodynamic Technologies on the MY 2015 Ford F150

Aero Technologies	Active grill shutters
	Underbody Cover
	Front corners and head lamps canted back for smooth air flow
	Rear spoiler integrated with the Tail gate (Air from the roof lands on the spoiler before trailing off thereby reducing turbulence behind the truck
	Cargo box narrower than the cab and trim piece between the cab and pickup box
	Rear tail lamps shaped for smooth air flow tailing off and reducing turbulence
	Duct under head lamp channels air to the wheel house thereby reducing wake generated by the w heel, Cross sectional area slightly larger than previous gen which resulted in some loss of benefits. More information is provided by Ford at the following link

[1005] PRIA at 433.
[1006] https://media.ford.com/content/fordmedia/fna/us/en/news/2015/07/15/how-air-curtains-on-f-150-help-reduce-aerodynamic-drag.html.

The Nissan Murano is an example of a mid-size SUV with greater than fifteen (15) percent improvement in aerodynamic drag values compared to the previous generation. The SAE paper published in 2015 outlines the specifics of aerodynamics in the Nissan Murano,[1007] and they include those listed in Table VI-75Table VI-75 below.

The exterior of this vehicle was completely redesigned from the MY 2013-2014 generation with the goal of minimizing aerodynamic drag by combining passive aerodynamic devices with an optimized vehicle shape. The primary passive devices employed include optimization of the rear end shape to reduce rear end drag, and addition of a large front spoiler to reduce underbody air flow and redirect it toward the roof of the vehicle, thus augmenting the rear end drag improvements. Other passive improvements include plastic fillet moldings at the wheel arches, raising the rear edge of the hood, shaping the windshield molding and front pillars, engine under-cover and floor cover, and air deflectors at the rear wheel wells. An active lower grille shutter also redirects air over the body when closed. Together, these measures for the MY 2015 model, achieved a drag coefficient of 0.31, representing a 16 to 17 percent improvement over the 0.37 Cd of the previous model.

Table VI-75 – Aerodynamic Technologies on MY 2015 Nissan Murano

Design	Detail
Ideal Flow Features	
Minimum airflow into engine compartment	Reduces resistance (just enough to cool)
Airflow under front bumper toward underbody minimized	Reduce as much flow as possible underbody to reduce resistance caused by the uneven floor
Flow around ends of front bumper toward body sides	Reduce drag, covers front of front tires
Airflow at front wheel arches is routed alongside surfaces of front tires	Reduce resistance that occurs at the front surfaces of the tires
Separation angle at rear of hood is large	Minimize resistance by reducing pressure at low end of windshield, 'hide' windshield wipers and reduce rain droplets in area of air flow
Smooth area at front pillars toward body sides	Vertical vortices are minimized to reduce drag
Optimize of the rear end shape	Assure clean separation of airflow from rear to minimize drag, and equate velocity of airflow from over roof and along body sides as much as possible to minimize vortices.
Floor -lower bottom edge of front bumper	Reduces airflow toward underbody, route airflow toward vehicle rear in straight path to minimize flow resistance caused by the uneven floor. Airflow at front of wheelhouses is minimized and wheelhouse design is optimized to direct the air trapped inside rearward - all to reduce resistance at the back of the wheel arches.
Computational Fluid Dynamics (CFD) Simulations (80 simulations)	

[1007] SAE Paper 2015-01-1542.

Active Lower grille shutter at lower opening	Redirects air over the body when closed Higher opening allows sufficient air when grill shutter closed Duct type structure is used to provide direction to the airflow to the heat exchanger and minimize entry into engine compartment elsewhere
Large front spoiler beneath front bumper	Reduces underbody airflow and redirect toward roof of the vehicle Bottom edge is provided with a lip to increase the flow separation angle to reduce airflow further under the body (similar impact as a further lowering the bottom edge of the front spoiler)
Plastic fillet moldings at the wheel arches	To assure air flows along the side surfaces of the front tires (avoid adjusting design of front bumper ends)
Optimize shape of rear edge of hood	To promote separation by increasing flow separation angle, distance windshield wipers from airflow, reduce collection of water droplets
Optimize windshield molding shape	To smooth for wind. flow
Outside mirrors optimized for placement	Avoid airflow coming over rear edge of hood and lower edge of front pillar
Optimize shape of vehicle rear end	Shape of rear spoiler, rear combination lamps and rear bumper optimization. Secure larger roof approach resulted in increased pressure recovery and reduced drag by wake flow.
Overall vehicle shape and equal airflow	Balance roof flow and body side flow to reduce vortices
Design optimization to increase airflow to roof	Reduces rear drag caused by wake flow
Rear Spoiler part of roof approach	Tapered toward vehicle rear
Engine under-cover and floor cover	Covers beneath front bumper and over suspension links and muffler piping, raise fuel tank, resulting in smooth underbody flow of air (not full cover)
Reduce airflow into wheelhouses	Large front spoiler extends as far as the front of the wheelhouses and deflectors (optimally shaped) in front of the rear tires, bottom of front spoiler lowered on both sides as capable (governed by ground clearance)
Smoother fenders	Reduce gaps between closure panels
Small vortex-creators	Put vortices in desired places to minimize drag

A combination of a slightly lighter MY 2015 Nissan Murano (on average lighter by 94 lbs. considering all trim levels), relative to previous generation, and combination of engine improvements (comparing 3.5L V6 in MY 2014 to 3.5L V6), and improvements in transmission resulted in overall improvement in fuel economy.[1008] Similar to MY 2015 F150, the real-world fuel economy improvement directly attributable to aerodynamic technologies is uncertain.

Consequently, the agencies disagree with ICCT that the availability of aerodynamic technologies was artificially limited by assigning higher baseline levels in the analysis fleet. The

[1008] https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=34457&id=37198 (last visited 12.12.2019) shows 20 mpg (combined) in MY2014 Nissan Murano (3.5L VQ35DE V6 with Variable gear ratio transmission) and 24 mpg (combined in MY2015 Nissan Murano (3.5L VQ35DE V6 with Automatic AV S7 transmission)).

agencies also declined to conduct the two sensitivity cases that ICCT recommended. First, as discussed above, vehicles in production are clearly employing varying levels of aerodynamic improvements. Assuming every vehicle in the analysis fleet is set to 0 percent aerodynamic improvement would not demonstrate how the agencies' decision to assign technology levels in the analysis fleet affected the compliance scenarios. Allowing vehicles in the analysis fleet to artificially achieve more aerodynamic reduction improvements than are actually available in the real world would result in an artificial overstated effectiveness improvements and understated costs to achieve higher stringency levels.

Commented [A258]: REVISE: It's evident that ICCT realizes this; however, the reason to do a sensitivity case with all AERO0 is not to reflect a "real" fleet, it's to bound the problem in a way that will indicate how significant various asumptions are. The fact that it "would result in an artificial overstated effectiveness improvements," which everyone knows a priori, is not a valid reason to reject the idea.

Second, as discussed above, baseline aerodynamic levels in the Draft TAR were based on road load coefficients, which required the agencies to make assumptions, leading to baseline assignments that were not accurate. In the NPRM, the agencies discussed in the tradeoffs between building the analysis fleet using confidential information from manufacturers and publicly available data on the vehicles.[1009] In the case of drag coefficient values, which cannot be gleaned from publicly available information, except in cases where a manufacturer chooses to publicly release that data, or by simply observing a vehicle, the agencies decided that the improved accuracy associated with using manufacturer-provided C_d values outweighed the benefits for using publicly releasable C_d estimates based on road load coefficients, especially as manufacturer-provided C_d values are only used to assign initial aerodynamic improvement levels relative to C_d values for each body style segment in the MY 2015 fleet. In addition, as detailed above, manufacturers had submitted comments that the Draft TAR approach to baseline fleet assignments had underestimated technology already present on vehicles, leading the analysis to apply more aerodynamic drag reduction technology than could be applied in the real world.

This also relates to ICCT's comment that the agencies must share the basis for any aerodynamic calculation and exact estimated percent improvement (rather than binned percentage categories) for each vehicle make and model in the baseline and future modeled fleet, and their technical justification for each value. As discussed above, the agencies shared the relative performance approach methodology for assigning baseline aerodynamic levels to vehicles in the analysis fleet in detail in the PRIA,[1010] and this approach was the basis for the aerodynamic calculation performed for every vehicle make and model in the analysis fleet. The agencies provided the summary of aerodynamic drag coefficients (including averages for MY 2016 vehicles) by vehicle body style,[1011] and the baseline aerodynamic improvement assignments for each vehicle model were included in the NPRM Market Data File. In addition, because aerodynamic drag information from manufacturers is provided as confidential business information, the agencies are unable to disclose that specific information. However, as discussed above, the agencies are closely examining the data provided and comparing it to other available information to assess the best estimate for aerodynamic technology for each vehicle in the analysis fleet.

[1009] 83 FR 43004.
[1010] PRIA at 441.
[1011] PRIA at 443.

For these reasons, the agencies continued to use the NPRM methodology to assign aerodynamic drag reduction improvements for the MY 2017 vehicle fleet for this final rule.

c) Aerodynamic Drag Technology Adoption Features

As discussed above, the agencies used a relative aerodynamic drag reduction performance approach to assign current aerodynamic technology level to a vehicle.[1012] For some body styles with different utility, such as pickup trucks, SUVs and minivans, frontal area can vary, and this can affect the overall aerodynamic drag forces. In order to maintain vehicle utility and functionality related to passenger space and cargo space, the agencies assumed all technologies that improve aerodynamic drag forces would do so through reducing the C_d while maintaining frontal area.

In the NPRM, the agencies noted that the Proposed Determination analysis assumed that some vehicles from all body styles could (and would) reduce aerodynamic forces by 20 percent, which in some cases led to future pickup trucks having aerodynamic drag coefficients better than some of today's typical cars, if frontal area were held constant in order to preserve interior space and cargo space. The agencies further noted that for some vehicle types, there was limited practical capability to significantly improve aerodynamic drag coefficients over baseline levels. In those cases, the agencies deemed the most advanced levels of aerodynamic drag simulated as not technically practicable given the need to maintain vehicle functionality and utility, such as interior volume, cargo area, and ground clearance.

The industry had also commented in response to EPA's Proposed Determination on the difficulty to achieve AERO20 improvements for certain body styles. In the NPRM, the agencies considered the industry comments along with the observations made in the MY 2016 fleet, and tentatively determined the maximum feasible improvement in C_d that could be achieved for pickup trucks is AERO15 level.[1013] Similarly, the agencies determined the maximum feasible improvement in C_d that could be achieved for minivans is AERO10. Next, the NPRM analysis did not apply 15 percent or 20 percent aerodynamic drag coefficient reduction to cars and SUVs with more than 405 horsepower. The agencies noted that many high-performance vehicles already include advanced aerodynamic features despite middling aerodynamic drag coefficients. In these high-performance vehicle cases, the agencies recognized that manufacturers tune aerodynamic features to provide desirable downforce at high speeds and to provide sufficient cooling for the powertrain, and, therefore, manufacturers may have limited ability to improve aerodynamic drag coefficients for high performance vehicles with internal combustion engines without reducing horsepower. Accordingly, the agencies did not allow application of AERO15 and AERO20 technology for all vehicles with more than 405 HP. Approximately 400,000 units of volume in the MY 2016 market data file included limited application of aerodynamic

[1012] CdA (Aerodynamic Drag Forces) = Coefficient of Drag x Frontal Area.

[1013] The agencies noted in the NPRM that, although ANL created full-vehicle simulations for trucks with 20 percent drag reduction, those simulations were not used in the CAFE modeling. The agencies concluded that level of drag reduction was likely not technologically feasible with today's technology, and the analysis accordingly restricted the application of advanced levels of aerodynamics in some instances, such as in that case, due to bodystyle form drag limitations.

technologies because of vehicle performance. The agencies sought comment on limiting the C_d improvement in these circumstances.

Ford commented in support of the agencies' decision to limit the application of AERO20 on pickup trucks, noting that limiting AERO20 on pickups is appropriate given the high inherent form drag associated with pickups' aerodynamic profile.[1014]

CARB commented that the agencies excluded AERO20 inconsistently across the fleet, noting that while some of the restrictions may be valid, the broad rule the agencies used resulted in technology being inappropriately excluded from too many vehicles.[1015] Specifically, CARB took issue with the majority of luxury sedans and SUVs being excluded from AERO20 because they had high horsepower engines, while the agencies did assign AERO20 to vehicles like the Tesla Model S and Model X SUVs, which have horsepower in excess of 405. CARB stated that while electrification provides a higher motivation to minimize road load through technologies such as aerodynamic reductions, implementing AERO20 reductions on high horsepower sedans and SUVs is clearly feasible and should not be artificially restricted in the CAFE model.

In addressing these comments, the agencies considered the relative cooling requirements for all electric powertrains and for high performance internal combustion engine powertrains since airflow diverted for cooling adversely impacts a vehicle's C_d. The peak heat rejection and engine cooling needs for high performance internal combustion engines is significantly higher than for all electric powertrains. Internal combustion engines convert a lower percentage of energy contained in gasoline into mechanical work (and other useful work, such as lighting and sound), and the energy not converted into mechanical work (or other useful work) is converted into heat. A significant amount of the waste heat must be handled by the cooling systems. Battery electric vehicles convert most of the electrical energy stored in the battery into mechanical work and other useful work, and therefore convert less energy into heat that must be handled by the cooling system. Also, electric powertrains can provide a degree of electric braking, whereas internal combustion engines exclusively use friction braking, which generates heat and requires greater cooling, particularly on vehicles with substantial braking performance capabilities. The agencies believe it is appropriate to account for these differences in considering the amount of aerodynamic improvement that can be implemented, and determined there are valid technical reasons for not applying AERO15 and AERO20 levels for vehicles with more than 405 HP in the final rule, just as was done for the NPRM.

d) Aerodynamic Drag Technology Effectiveness

The NPRM analysis included four levels of aerodynamic improvements, AERO5, AERO10, AERO15, and AERO20, representing 5, 10, 15, and 20 percent C_d improvements, respectively. Notably, the NPRM analysis assumed that aerodynamic drag reduction could only come from reduction in the aerodynamic drag coefficient and not from reduction of frontal area,

[1014] NHTSA-2018-0067-11928.
[1015] NHTSA-2018-0067-11873.

to maintain vehicle functionality and utility, such as passenger space, ingress/egress ergonomics, and and cargo space.[1016]

Ford commented in support of the agencies' decision to consider the frontal area and body style as "utility factors" and requiring that aerodynamic improvements come from reductions in Coefficient of Drag (C_d) and not from reductions in frontal area.[1017]

CBD commented that EPA staff had critiqued NHTSA's characterization of research on aerodynamic drag coefficients and the NPRM did not appear to incorporate or respond to this input,[1018] citing prepublication materials docketed pursuant to Section [X] of the Clean Air Act.[1019] Specifically, CBD stated that EPA staff had commented in respouse to the characterization that "[f]or some bodystyles, the agencies have no evidence that manufacturers may be able to achieve 15 percent or 20 percent aerodynamic drag coefficient reduction relative to baseline (for instance, with pickup trucks" and noted that "[i]n the past, EPA has assigned aero tech in the baseline relative to a "Null" and then applied drag reduction level against that Null in order to ensure that the maximum aero level (i.e., 15 or 20 percent) would always be achievable for all body styles." This comment reflects deliberative, in-process input from EPA staff. In fact, the NPRM text was developed by the agencies with the benefit of this and other input from EPA staff, and the NPRM clarified that reducing frontal area would likely degrade other utility features like interior volume or ingress/egress.

CARB commented, as part of its broader comments, that the agencies' effectiveness values were reduced relative to what EPA's LPM calculated, that the benefits of aerodynamic improvements were underestimated.[1020] Specifically, CARB cited the H-D Systems comparison of LPM benefits for AERO10 and AERO20 of 2.1 percent and 4.3 percent, respectively, compared with Autonomie benefits of 1.51 percent and 3.03 percent, respectively, and stated that the agencies' aualysis provided no description or cited any new data or evidence as to why they reduced the projected assumptions compared to what EPA's Lumped Parameter Model calculated.

H-D Systems also commented that the Autonomie modeling assumed no engine change when aerodynamic drag and rolling resistance reductions are implemented, as well as no changes to the transmission gear ratios and axle ratios, which vary by transmission type but not by the tractive load.[1021] HDS stated that the EPA ALPHA model adjusted for this effect, which accounted for the difference in technology effectiveness estimates that HDS characterized between the Draft TAR and NPRM. HDS provided a "correct estimate" for AERO20 effectiveness improvements of 4.3 percent, with the justification that there was no gear/axle ratio adjustment in the Autonomie analysis.

[1016] 83 FR 43047.
[1017] NHTSA-2018-0067-11928.
[1018] NHTSA-2018-0067-12000, at 188.
[1019] Docket No. EPA-HQ-OAR-2018-0283-0453, June 29, 2018 Comments at 93.
[1020] NHTSA-2018-0067-11873.
[1021] NHTSA-2018-0067-11985.

In response to HDS's comment, the Alliance submitted supplemental comments questioning the extent to which aerodynamics (and changes in top gear ratio) affect performance metrics held constant in the analysis, like low- and high-speed acceleration performance and gradeability.[1022] The Alliance cited a study for the proposition that vehicle acceleration is most influenced by engine power and weight, and also that bodystyle differences have a lesser impact on acceleration performance. The Alliance further commented that "[r]egarding changes in top gear ratios in response to aerodynamic changes, the Alliance is not aware of any examples in which a top gear ratio was changed solely due to aerodynamic improvements. There may be examples where a vehicle's top gear ratio was changed at the same time aerodynamic changes were made, but such changes would be made in response to the cumulative changes across the entire vehicle, not just aerodynamic improvements." The Alliance concluded that "[t]here are also practical manufacturing and investment constraints which limit the potential for applying engine changes in response to improved vehicle aerodynamics," citing the agencies decision to only resize engines with significant design changes, to account for product complexity and economies of scale.

In response to the Alliance's supplemental comment, HDS submitted supplemental comments stating that "[d]rag reduction is usually accomplished when a vehicle body is redesigned, so gear and axle ratios are typically re-optimized for the entire set of changes, but these changes include the drag reduction."[1023] HDS commented that the Alliance's comments acknowledged that calibration changes are made in response to tractive load changes, while the Autonomie analysis recalibrates the powertrain in response only to large mass reduction improvements, and not any other vehicle changes that reduce tractive load, like aerodynamic improvements, even when those changes would result in a greater tractive load reduction than a 10 percent mass reduction. HDS reiterated its statement that "[i]n the real world (and as captured in EPA's prior ALPHA model), automakers typically alter many vehicle attributes affecting tractive load simultaneously, including aerodynamics," and the Autonomie outputs underrepresent the benefit of tractive load reduction strategies by not optimizing engine efficiency after most changes in tractive load because the model employes fixed shift points, gear ratios, and axle ratios when drag or tire rolling resistance is reduced.

Regarding the first set of comments that the aerodynamic effectiveness values were reduced from EPA's values presented in the Draft TAR, that results from differences in the two modeling approaches. As discussed above, for this analysis the agencies decided that aerodynamic drag reduction could only come from reduction in the aerodynamic drag coefficient, and not from a reduction in vehicle frontal area, at least without reducing other attributes of the vehicle.[1024] ~~In contrast, EPA for the Draft TAR and Proposed Determination assumed that manufacturers could reduce frontal area as well as aerodynamic drag coefficient to achieve a 20 percent aerodynamic force reduction relative to an initial aerodynamic technology level. Also, as discussed in Section [Tech Effectiveness and Modeling], the agencies found that the use of the full vehicle simulation methodology used for the NPRM and for this final rule, provides more accurate estimates of effectiveness for individual technologies and combinations~~

[1022] NHTSA-2018-0067-12385, at 31-32.
[1023] NHTSA-2018-0067-12395, at 4-5.
[1024] 83 FR 43047; PRIA at 441.

~~of technologies than the methodology used for the EPA Draft TAR and Proposed Determination using the ALPHA and LPM tools, which provided more uncertain effectiveness estimates.~~

Commented [A259]: DELETE: The EPA ALPHA tool is also a full vehicle modeling tool, so the comment that Autonomie is superior on that front is difficult to understand.

Commented [A260]: DELETE: This is not an accurate characterization of EPA's modeling processes. As described in the Final Determination and SAE papers, EPA uses actual measured road load coefficients to both determine the appropriate levels of aero and non-aero drag on individual vehicles in the initial fleet. These are the same road load coefficients that are used in the ALPHA simulation, consistent with the dynamometer settings used for vehicle certification.

In Section [Tech Effectiveness and Modeling] and Section [Transmissions], the agencies provide a full discussion of the issues associated with assuming the engine and transmission can be optimized for every combination of technologies. It would be unreasonable and unaffordable to resize powertrains, including engines and transmission and axle ratios, for every unique combination of technologies, and exceedingly so for every unique combination technologies across every vehicle model due to the extreme manufacturing complexity that would be required to do so. Product complexity and economies of scale are real, and in the NPRM, engine resizing was limited to specific incremental technology changes that would typically be associated with a major vehicle or engine redesign.[1025] As noted by H-D Systems, the EPA Draft TAR and Proposed Determination analyses adjusted the effectiveness of every technology combination, including for aerodynamics technologies, assuming performance could be held constant for every combination. However, those analyses did not recognize or account for the extreme complexity nor the associated costs for that impractical assumption. The NPRM and final rule analyses account for these real-world practicalities and constraints, and doing so explains some of the effectiveness and cost differences between the Draft TAR/Proposed Determination and the NPRM/final rule. The agencies believe the NPRM and the final rule approach appropriately resizes powertrain components for specific incremental technology changes that would typically be associated with a major vehicle or engine redesign.

For the NPRM, and carried into the final rule analysis, Autonomie simulates all road load conditions (e.g., MR, AERO, and ROLL technology levels) for each engine and transmission combination. In addition, engines are resized for appropriate specific technology changes that would be associated with a major vehicle or engine redesign. Also, as discussed further in Section [Transmissions], many commenters seemed to conflate the practice in the analysis of using a common (same) gear set across vehicle configurations (to address manufacturing complexity) with using the same shift maps. As commenters stated, they assumed the same shift maps were applied across vehicle models. However, the shift initializer routine was run for every unique Autonomie full vehicle model configuration and generated customized shifting maps. The algorithms' optimization was designed to balance minimization of energy consumption and vehicle performance. This balance was necessary to achieve the best fuel efficiency while maintaining customer acceptability by meeting performance neutrality requirements. The agencies believe the level of optimization of engine size, transmissions, gear ratios and shift schedules reasonably approximates what is achievable and what manufacturers actually do.

e) Aerodynamic Drag Technology Cost

For the Draft TAR, the agencies relied on the 2015 NAS report to estimate the cost of AERO1 and AERO2 levels of aerodynamic drag coefficient improvements. The agencies received several comments related to the cost assumptions used in the Draft TAR, mainly that they were too low to meet AERO1 and AERO2 levels. The industry submitted confidential

[1025] *See* 83 FR 43027 (Aug. 24, 2018).

business information on the costs of passive aerodynamic technologies needed to achieve AERO1 (10 percent improvement in drag improvement), which showed a significantly higher estimated costs than assumed for the Draft TAR. Similarly, the industry submitted confidential business information on the costs of active aerodynamic technologies, including some high cost technologies. The industry also commented that some active aerodynamic technologies could only be implemented during vehicle redesigns and not during a mid-cycle vehicle refresh.

The agencies considered these comments and performed additional research to assess the costs for passive and active aerodynamic technologies. We revised the cost estimates for the NPRM, based in part on confidential information from the automotive industry, and from our own assessment of manufacturing costs for specific aerodynamic technologies from available sources. In general, the NPRM cost estimates were higher than Draft TAR cost estimates. The agencies included a high-level discussion in the PRIA that the cost to achieve AERO5 is relatively low, as most of the improvements can be made through body styling changes. The cost to achieve AERO10 is higher than AERO5, due to the addition of several passive aero technologies, and the cost to achieve AERO15 and AERO20 is higher than AERO10 due to use of both passive and active aero technologies.

The agencies did not receive any comments on the costs of aerodynamic improvements, and accordingly, for the final rule, as shown in Table VI-76Table VI-76 and

Table VI-77

Table VI-77 below, the agencies used the same aerodynamic improvement costs presented in NPRM.

Table VI-76 – Aerodynamic Improvement Technology Costs for Passenger Cars and SUVs for MY 2017 (in 2018$)

Aero Improvements for Passenger Cars and SUV	$ DMC (2018$)	RPE
0%	$0.00	
5%	$39.38	$59.07
10%	$80.51	$120.76
15%	$113.76	$170.64
20%	$201.27	$301.91

Table VI-77 – Aerodynamic Improvement Technology Costs for Pickup Trucks for MY 2017 (in 2018$)

Aero Improvements of Pickups	$ DMC (2018$)	RPE
0%	$0.00	

5%	$39.38	$59.07
10%	$80.51	$120.76
15%	$201.27	$301.91
20%	$525.06	$787.59

6. Tire rolling resistance

Tire rolling resistance is a road load force that arises primarily from the energy dissipated by elastic deformation of the tires as they roll. Tire design characteristics (for example, materials, construction, and tread design) have a strong influence on the amount and type of deformation and the energy it dissipates. Designers can select these characteristics to minimize rolling resistance. However, these characteristics may also influence other performance attributes, such as durability, wet and dry traction, handling, and ride comfort.

Low rolling resistance tires are increasingly specified by OEMs in new vehicles and are also increasingly available from aftermarket tire vendors. They commonly include attributes such as higher inflation pressure, material changes, tire construction optimized for lower hysteresis, geometry changes (e.g., reduced aspect ratios), and reduced sidewall and tread deflection. These changes are commonly accompanied by additional changes to vehicle suspension tuning and/or suspension design to mitigate any potential impact on other performance attributes of the vehicle.

Lower-rolling-resistance tires have characteristics that reduce frictional losses associated with the energy dissipated mainly in the deformation of the tires under load, thereby improving fuel economy and reducing CO_2 emissions. The agencies considered two levels of improvement for low rolling resistance tires in the analysis: the first level of low rolling resistance tires considered reduced rolling resistance 10 percent from an industry-average baseline, while the second level reduced rolling resistance 20 percent from the baseline.

Walter Kreucher commented that the agencies should eliminate low rolling resistance tires from the list of viable technologies, in recognition of the safety impacts of low rolling resistance tires in relation to stopping distance and accident rates.[1026] Separately, Mr. Kreucher argued that the model should reflect the safety impact of low rolling resistance tires.

The agencies have been following the industry developments and trends in application of rolling resistance technologies to light duty vehicles. As stated in the NAP special report on Tires and Passenger Vehicle Fuel Economy,[1027] cited by Mr. Kreucher, national crash data does not provide data about tire structural failures specifically related to tire rolling resistance, because the rolling resistance of a tire at a crash scene cannot be determined. However, other

[1026] NHTSA-2018-0067-0444.
[1027] Tires and Passenger Vehicle Fuel Economy: Informing Consumers, Improving Performance - - Special Report 286 (2006), available at https://www.nap.edu/read/11620/chapter/6.

metrics like brake performance compliance test data are helpful to show trends like that stopping distance has not changed in the last ten years,[1028] during which time many manufacturers have installed low rolling resistance tires in their fleet—meaning that manufacturers were successful in improving rolling resistance while maintaining stopping distances through tire design, tire materials, and/or braking system improvements. In addition, NHTSA has addressed other tire-related issues through rulemaking,[1029] and continues to research tire problems such as blowouts, flat tires, tire or wheel deficiency, tire or wheel failure, and tire degradation.[1030] However, there are currently no data connecting low rolling resistance tires to accident or fatality rates.

With better tire design, tire compound formulations and improved tread design, tire manufacturers have tools to balance stopping distance and reduced rolling resistance. As stated in one article referenced by Mr. Kreucher, tire manufacturers can use "higher performance materials in the tread compound, more silica as reinforcing fillers and advanced tread design features" to mitigate issues related to stopping distance.[1031] The agencies do not believe that there is sufficient data or other information to support removing low rolling resistance tires as a viable technology considered in the CAFE and CO_2 analysis at this time.

HDS argued, as discussed further below, that based on available data on current vehicle models and the likely possibility that there would be additional tire improvements over the next decade, the agencies should consider ROLL30 technology, or a 30 percent reduction of tire rolling resistance over the baseline.[1032]

As stated in Joint TSD for the 2017-2025 final rule, tire technologies that enable rolling resistance improvements of 10 and 20 percent have been in existence for many years.[1033] Achieving improvements of up to 20 percent involves optimizing and integrating multiple technologies, with a primary contributor being the adoption of a silica tread technology. Tire suppliers have indicated that additional innovations are necessary to achieve the next level of low rolling resistance technology on a commercial basis, such as improvements in material to retain tire pressure, tread design to manage both stopping distance and wet traction, and development of carbon black material for low rolling resistance without the use of silica to reduce cost and weight.[1034] The agencies are continuously monitoring these and other tire technology improvements. The agencies believe, the tire industry is in the process of moving the industry towards first level of low rolling resistance technology across the vehicle fleet (10 percent reduction in rolling resistance), and that 20 percent improvement is achievable in the rulemaking timeframe. However, the agencies believe that at this time, the emerging tire technologies that

[1028] https://one.nhtsa.gov/cars/problems/comply/index.cfm.
[1029] 49 CFR 571.138, Tire pressure monitoring systems.
[1030] Tire-Related Factors in the Pre-Crash Phase, DOT HS 811 617 (April 2012), available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811617.
[1031] Jesse Snyder, A big fuel saver: Easy-rolling tires (but watch braking) (July 21, 2008), https://www.autonews.com/article/20080721/OEM01/307219960/a-big-fuel-saver-easy-rolling-tires-but-watch-braking. Last visited December 3, 2019.
[1032] NHTSA-2018-0067-11985.
[1033] EPA-420-R-12-901, at page 3-210.
[1034] Assessment of Fuel Economy Technologies for Light-Duty Vehicles (2011) at page 103.

would achieve 30 percent improvement in rolling resistance will not be available for commercial adoption in the fleet during the rulemaking timeframe.[1035] As a result, the agencies decided not to incorporate 30 percent reduction in rolling resistance technology for this final rule.

a) Rolling Resistance Modeling in the CAFE Model

The two levels of rolling resistance technology considered in the analysis include ROLL10 and ROLL20, which represent a 10 percent and 20 percent rolling resistance reduction from the baseline (ROLL0), respectively.

To understand the following discussions about rolling resistance analysis fleet assignments and effectiveness values, it is important to understand how the agencies developed the baseline value (ROLL0) used in prior analyses, and how the agencies developed the baseline value used in the NPRM and final rule. In the Draft TAR, the agencies used unique baseline rolling resistance coefficients for each vehicle class. Specifically, the compact car class value was 0.0075, the midsize car value was 0.008, the small SUV value was 0.0084, the midsize SUV value was 0.0084, and the pickup truck value was 0.009. The PRIA described that since the Draft TAR, the agencies had reassessed rolling resistance values for contemporary tires through discussions with vehicle manufacturers, tire manufactures, and independent bench testing. Based on a thorough review of confidential business information submitted by industry, and a review of other literature, including the CARB/CONTROLTEC study mentioned below, the baseline rolling resistance coefficient for all vehicle classes was updated to 0.009 for the NPRM analysis. The agencies concluded that the updated baseline value brought the NPRM simulations into better alignment with tires in the MY 2016 analysis fleet. The agencies also discussed that updated value was consistent with the findings of the CONTROLTEC study on vehicle road loads, sponsored by CARB.[1036] The following figure shows the distribution of estimated tire rolling resistance coefficient values for the 1,358 MY 2014 vehicles evaluated in the CONTROLTEC/CARB study.

[1035] https://www.sveafordon.com/media/42060/SVEA-Presentation_Davari_public.pdf. Last visited December 30, 2019.

[1036] Technical Analysis of Vehicle Load Reduction Potential for Advanced Clean Cars, https://www.arb.ca.gov/research/apr/past/13-313.pdf, page 39.

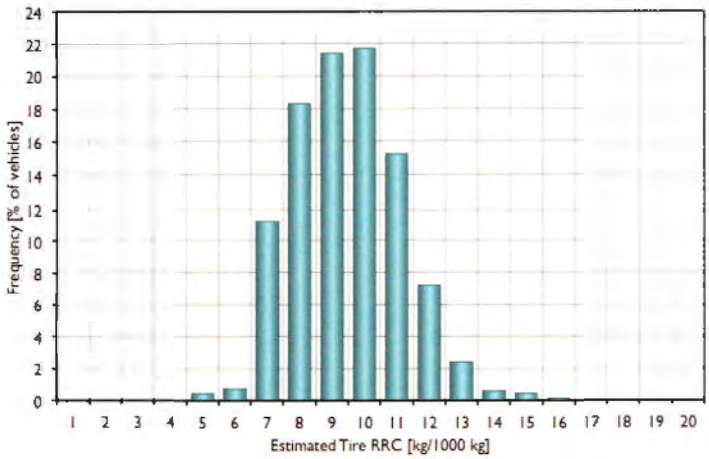

Figure VI-27 - Estimated tire rolling resistance for all vehicles from CONTROLTEC study

ICCT commented that it was "quite confusing and perhaps troubling" that the agencies adopted a higher average rolling resistance coefficient than that of the Draft TAR, "as it would imply that the fleet rolling resistance got worse, but the agencies are deciding to provide baseline credit as if there was more rolling resistance technology deployed."[1037] ICCT stated that the change appeared to be attributed to the agencies' use of CBI on tire rolling resistance received since the Draft TAR.

As described in the PRIA, the values used in the Draft TAR represented the "Best in Class" values in each of the vehicle classes and this did not necessarily reflect the average "Rolling Resistance Coefficient" (RRC) of the fleet. For the Draft TAR, the agencies did not have access to manufacturer confidential business information and relied on estimates from CONTROLTEC. As stated earlier, Figure VI-27Figure VI-27 shows the distribution of the estimated RRC for 1,358 vehicles models. The average RRC from the CONTROLTEC study (0.009) aligned with the NPRM estimate which was based in part on manufacturer submitted confidential business information. CONTROLTEC compared the estimated RRC data with the values provided by Rubber Manufacturers Association (renamed as USTMA-U.S. Tire Manufacturers Association) for original equipment tires. The average RRC from the data provided by RMA was 0.0092,[1038] compared to average of 0.009 from CONTROLTEC. CONTROLTEC attributed the difference due to analysis assumption, tire loading during coast down vs. load during tire testing, inflation pressure during coast down vs. inflation pressure

[1037] NHTSA-2018-0067-11741 full comments.
[1038] Technical Analysis of Vehicle Load Reduction by CONTROLTEC for California Air Resources Board (April 29, 2015) at page40.

during tire testing, coast down test reporting issues, tire types represented in the sample, tire break-in, and advancement in tire rolling resistance since the time RMA collected the data.

CONTROLTEC also stated that RRC values for some vehicles fell below the average RRC (indicating better performance) due to estimation assumptions for vehicles where manufacturer data was not available, and coast down test reporting issues.[1039] Further, CONTROLTEC performed a sensitivity study by mathematically removing aerodynamic contribution from the coast down coefficients. It was observed that the average RRC without the aerodynamic contribution is around 0.011. Accordingly, the agencies believe that it was reasonable to use 0.009 as the average RRC for the fleet for the NPRM and to continue to use that value for the final rule, based on the latest available data from manufacturers and alignment with the average RRC to the CONTROLTEC study estimate.

H-D Systems (HDS) commented that the CONTROLTEC/CARB study showed that there is a very significant fraction of the fleet with tire rolling resistance coefficients above 10kg/1000 kg, and a small percentage of vehicles with rolling resistance coefficients already at 0.05 or 0.06. HDS stated that NHTSA's baseline of 0.09 appeared "a little low but may be appropriate if the distribution was sales weighted." HDS argued that a number of vehicle models already have tires below 0.07, and the likelihood that there would be additional tire improvements over the next decade are likely, meaning that ROLL30 technology—or a 30 percent reduction of the tire rolling resistance coefficient to 0.063—is possible and appropriate for MY 2025.

Roush commented that rolling resistance is erroneously assumed to be the same across different vehicle classes, and that rolling resistance would vary depending upon the vehicle size, power, acceleration and performance package.[1040] As explained earlier, the RRC values used in the CONTROLTEC study were a combination of manufacturer information, estimates from coast down tests for some vehicles, and application of tire RRC values across other vehicles on the same platform. CONTROLTEC stated that some RRC values were below the estimated average (showing significant improvement from the baseline) due to assumptions that were applied to some vehicles when manufacturer data was not available. Further, some of the RRC estimates were based on vehicle coast down tests which had errors.[1041] As a result, some of the RRC values used in the Draft TAR showed significant improvements (30 percent reduction in rolling resistance relative to baseline), as observed by HDS. Based on a review of manufacturer-submitted confidential business information and other sources, the agencies are unaware of any tires in production which have 30 percent reduction in rolling resistance relative to baseline values.

As stated earlier, the baseline values used for the Draft TAR analysis were "Best in Class" values from the estimates developed by CONTROLTEC and not representative of the average of the fleet or average for the vehicle classes. For the NPRM, the agencies revisited the ROLL technology assignments based on the RRC values provided by manufacturers, and the

[1039] Technical Analysis of Vehicle Load Reduction by CONTROLTEC for California Air Resources Board (April 29, 2015) at page 38.
[1040] NHTSA-2018-0067-11984.
[1041] Technical Analysis of Vehicle Load Reduction by CONTROLTEC for California Air Resources Board (April 29, 2015) at page 38.

average RRC for each of the vehicle class was near the fleet average (RRC = 0.009). As shown in Figure VI-28 a vast majority of the vehicles in the fleet are in the ROLL0 bin across the different vehicle class, vehicle size, power, acceleration and performance configurations. For these reasons, the agencies will continue to use the fleet average of RRC=0.009 as the baseline value to assess ROLL technology improvements.

b) Rolling Resistance Analysis Fleet Assignments

As discussed above, NHTSA's Draft TAR analysis showed little rolling resistance technology in the baseline fleet for three reasons; the simulations used baseline values already reflecting best-in-class tire rolling resistance, credible tire rolling resistance values for all vehicles from bench data were not available to the agencies at the time of Draft TAR, and few manufacturers submitted rolling resistance values for the Draft TAR analysis.

For the NPRM, baseline (ROLL0) rolling resistance values were updated to 0.009, and any better rolling resistance values were assigned based on whether information indicated that vehicle had technology at least 10 percent better than baseline (.0081 or better for ROLL10), or at least 20 percent better than baseline (.0072 or better for ROLL20). The agencies used confidential business information provided by manufacturers to assign initial rolling resistance values for each vehicle make and model.

The Alliance commented that the NPRM MY 2016 analysis fleet had been updated with appropriate ratings of rolling resistance improvements, compared to the Draft TAR where vehicles were generally considered to have unimproved tires (meaning the Draft TAR assumed additional improvements were more achievable than in reality). The Alliance noted that the Draft TAR approach led to the CAFE model adding additional tire rolling resistance improvements despite the fact that manufacturers had already made significant improvements with that technology. This meant that the real-world fleet had little remaining opportunity for additional tire-related improvements, ultimately leading to the Draft TAR analysis underpredicting the amount of powertrain technology required for compliance.

The Alliance noted that it is possible to estimate rolling resistance features of a vehicle using road load coefficients, but the process requires various assumptions and is not very accurate. The Alliance concluded that the agencies' use of CBI to assign baseline technology levels correctly was an accurate and practical solution. Similarly, Ford commented in support of the agencies' low rolling resistance tire assignments in the baseline fleet, stating that the accuracy of the baseline fleet assessment had been considerably improved using actual tire rolling resistance data.[1042]

HDS commented that the analysis fleet "accounts for the distribution of tires below 0.09 as 19% of vehicles in MY 2016 are modeled as having used ROLL10 and 25% of vehicles as having used ROLL20 in the base year, but there is no accounting for the ~25% of vehicles having RRC values 10 to 20% above the 0.09 RRC average." HDS concluded that "[a] stricter accounting of the baseline and, possibly setting specific lower limits for 2025 RRC by vehicle

[1042] NHTSA-2018-0067-11928.

type (as done for aero drag in the PRIA) will show significant additional fleetwide effectiveness from RRC reduction which is a very cost-effective technology."

ICCT commented that the agencies made a "dramatic and unjustified" shift in baseline tire rolling resistance assignments from the 2015 fleet used in the Draft TAR to the 2016 fleet used in the NPRM.[1043] ICCT noted that per the agencies' updated baseline value, nearly 20 percent of all vehicles in the MY 2016 analysis fleet achieved 0.0081 (or better) rolling resistance value, and more than 26 percent achieve 0.0072 (or better). ICCT argued that rather than changing the definition of rolling resistance technology to include improvements beyond the baseline, the agencies instead redefined the technology available, reducing the number of vehicles that can use tire improvements in future compliance years within the modeling framework, which artificially forced companies to use other, more expensive technologies.

ICCT stated that to substantiate the baseline rolling resistance assignments, the agencies need to show data on how these improvements are evident in the fleet and delivering benefits. ICCT alleged that if an improvement of that magnitude were true, it would be evident in fleet level miles-per-gallon and CO_2 levels; however, "none of the quantifiable mpg or CO_2 benefits that would be associated with these additional rolling resistance improvements were reflected with any real-world evidence in the model year 2016 fleet." ICCT stated this seemed to be a case of the agencies "artificially burying efficiency technology in the baseline, rendering it unusable in the post model year 2016 compliance scenarios."

ICCT also stated that the agencies must share absolute road load coefficients for each vehicle make and model in the baseline fleet, and the technical justification for each value, in addition to conducting two sensitivity analysis cases "assum[ing] that every baseline make and model is set to 0% rolling resistance improvement and set to the previous baseline rolling resistance (from the Draft TAR) to demonstrate how much the agencies' decision to load up more baseline technology affects the compliance scenarios, as it appears that the agencies may have made a unsupportable and non-rigorous assumption about rolling resistance technology across the models." ICCT concluded that because the changes were buried in the datafiles and unexplained, the agencies must issue a new regulatory analysis and allow an additional comment period for review of the methods and analysis.

Based on the comments from HDS and ICCT, the agencies reexamined available tire rolling resistance data. The assignment of ROLL20 technology was revised for some vehicle models based on information on the use of common tires across vehicles that shared a platform. As a consequence, for the final rule, only 20 percent of the MY2017 vehicle fleet is assigned ROLL20. The agencies will continue to investigate additional methods to improve the accuracy of this method, however as the Alliance and Ford noted, the accuracy of the baseline levels had been significantly improved over prior analyses by using actual tire RRC data. The agencies approach is consistent with the NAS recommendation to have two ROLL technology levels. The agencies determined that 30 percent rolling resistance improvement while maintaining other tire characteristics is unlikely to be available in the rulemaking timeframe.

[1043] NHTSA-2018-0067-11741 full comments.

The Figure VI-28 shows the distribution of ROLL technology for the Draft TAR, NPRM and final rule. For the NPRM, 64 percent of the MY 2016 vehicle fleet was assigned ROLL0 and for the final rule, 59 percent of the MY2017 vehicle fleet is assigned ROLL0. This shows that the majority of the fleet is still at the ROLL0 technology level and there is still significant opportunity for the vehicle fleet to improve ROLL technology.

Figure VI-28 - Distribution of tire rolling resistance technology for the Draft TAR, NPRM and Final Rule

ROLL	Draft TAR (MY 2015 vehicle fleet	NPRM (MY2016 vehicle fleet)	Final Rule (MY2017 vehicle fleet)
ROLL0	99.80%	64%	59%
ROLL10	0.1%	10%	21%
ROLL20	0.1%	26%	20%

c) Rolling Resistance Adoption Features

In some cases, low rolling resistance tires can affect traction, which may adversely impact acceleration, braking and handling characteristics for some high-performance vehicles. Similar to past rulemakings, the agencies recognized in the NPRM that to maintain performance, braking and handling functionality, some high-performance vehicles would not adopt low rolling resistance tire technology. For cars and SUVs with more than 405 horsepower (hp), the agencies restricted the application of ROLL20. For cars and SUVs with more than 500 hp, the agencies restricted the application of any additional rolling resistance technology (ROLL10 or ROLL20). The agencies developed these cutoffs based on a review of confidential business information and the distribution of rolling resistance values in the fleet.

Ford commented that the NPRM analysis appropriately limited the application of ROLL technology where it would be infeasible or would be at odds with the vehicles' intended function, characterizing that the decision to restrict application of ROLL10 and ROLL20 for high performance vehicles as reasonable.[1044]

Accordingly, the agencies continued with the NPRM methodology of restricting certain ROLL technology for high performance vehicles. In the final rule, we restricted the ROLL technology to ROLL0 and ROLL10 for vehicles with greater than 405 hp and below 505hp. For vehicles greater than 505hp, we restricted the ROLL technology to ROLL0.

d) Rolling Resistance Effectiveness Modeling and Resulting Effectiveness Values

As discussed above, the agencies updated the baseline rolling resistance value to 0.009, based on a thorough review of confidential business information submitted by industry, and a

[1044] NHTSA-2018-0067-11928.

review of other literature. To achieve ROLL10 in the NPRM and for the final rule analysis, the tire rolling resistance must be at least 10 percent better than baseline (.0081 or better). To achieve ROLL20, the tire rolling resistance must be at least 20 percent better than baseline (.0072 or better).

HDS commented that the Autonomie modeling assumed no engine change when drag and rolling resistance reductions were implemented, as well as no change to the transmission gear ratios and axle ratios, which vary by transmission type but not by the tractive load.[1045] HDS stated that "reduction in rolling resistance is accompanied by axle ratio adjustments so that the engine operates at about the same load but at lower RPM. The EPA ALPHA model adjusts for this effect, which accounts for the difference in benefit estimates" between Autonomie and the ALPHA model simulations.

As stated in the "Technology Effectiveness and Modeling" section, Autonomie builds performance-neutral vehicle models by resizing engines, electric machines, and hybrid electric vehicle battery packs only at specific incremental technology steps. To address product complexity and economies of scale, engine resizing is limited to specific incremental technology changes that would typically be associated with a major vehicle or engine redesign.[1046] Manufacturers have repeatedly told the agencies that the high costs for redesign and the increased manufacturing complexity that would result from resizing engines for small technology changes preclude them from doing so. It would be unreasonable and unaffordable to resize powertrains for every unique combination of technologies, and exceedingly so for every unique combination technologies across every vehicle model due to the extreme manufacturing complexity that would be required to do so. The agencies explained in the NPRM that the analysis should not include engine resizing with the application of every technology or for combinations of technologies that drive small performance changes to reflect better what is feasible for manufacturers.[1047]

Compliance modeling in the CAFE model also accounts for the industry practice of platform, engine, and transmission sharing to manage component complexity and associated costs.[1048] At a vehicle refresh cycle, a vehicle may inherit an already resized powertrain from another vehicle within the same engine-sharing platform that adopted the powertrain in an earlier model year. In the Autonomie modeling, when a new vehicle adopts fuel saving technologies (such as ROLL technology) that are inherited, the engine is not resized (the properties from the baseline reference vehicle are used directly and unchanged) and there may be a small change in vehicle performance.

[1045] NHTSA-2018-0067-11985.

[1046] *See* 83 FR 43027 (Aug. 24, 2018).

[1047] For instance, a vehicle would not get a modestly bigger engine if the vehicle comes with floor mats, nor would the vehicle get a modestly smaller engine without floor mats. This example demonstrates small levels of mass reduction. If manufacturers resized engines for small changes, manufacturers would have dramatically more part complexity, losing economies of scale.

[1048] Ford EcoBoost Engines are shared across ten different models in MY2019. https://www.ford.com/powertrains/ecoboost/. Last accessed Nov. 05, 2019.

Regarding customizing transmission gear ratios as rolling resistance changes are implemented, the agencies explained in Section [Transmissions] that it is an observable practice in industry to use a common gear set across multiple platforms and applications. The most recent example is the GM 10L90, a 10-speed automatic transmission that used the same gear set in both pick-up truck and passenger car applications.[1049] In Autonomie, optimization of transmission performance is achieved through shift control logic rather than customized hardware (e.g., gear ratios) for each vehicle line. The shift initializer routine was run for every unique Autonomie full vehicle model configuration to generate customized shifting maps. The algorithms' optimization was designed to balance minimization of energy consumption against vehicle performance.[1050] This balance was necessary to achieve the best fuel efficiency while maintaining customer acceptability by meeting performance neutrality requirements. See Section [Performance Neutrality] for more details. If the systems were over-optimized for our modeling, such as applying a unique gear set for each individual vehicle configuration, the analysis would likely over-predict the reasonably achievable fuel economy improvement for the technology. Over-prediction would be exaggerated when applied under real-world large-scale manufacturing constraints necessary to achieve the estimated costs for the transmission technologies.

As HDS noted, the EPA Draft TAR and Proposed Determination analyses performed using the ALPHA model adjusted the effectiveness of every technology combination assuming performance could be held constant for every combination, and did not recognize or account for the extreme complexity nor the associated costs for that impractical assumption. The NPRM and final rule analyses account for real-world practicalities and constraints related to both engine adoption and transmission adoption when other vehicle technologies are implemented, which explains some of the effectiveness and cost differences between the Draft TAR/Proposed Determination and the NPRM/final rule.

e) Rolling Resistance Cost

For the NPRM, the analysis used DMC for ROLL technology from the Draft TAR and updated the values to reflect 2016$ dollars. The agencies continued to use the same cost assumptions presented in the NPRM for the final rule, and updated the values to 2018$ dollars. Table VI-78Table VI-78 and Figure VI-29 show the different levels of tire rolling resistance technology cost.

[1049] "GM Global Propulsion Systems - USA Information Guide Model Year 2018" (PDF). General Motors Powertrain. Retrieved September 26, 2019. https://www.gmpowertrain.com/assets/docs/2018R_F3F_Information_Guide_031918.pdf.
[1050] *See* [FRM ANL Model Documentation file].

Table VI-78 - Cost for tire rolling resistance technologies relative to ROLL0

	Tire Rolling Resistance Technology Costs for MY 2017 (2018$)		
Technology	Direct Manufacturing Cost	RPE	Incremental to
ROLL0	$0.00	$0.00	Base V
ROLL10	$5.186	$7.78	Base V
ROLL20	$40.54	$60.81	Base V

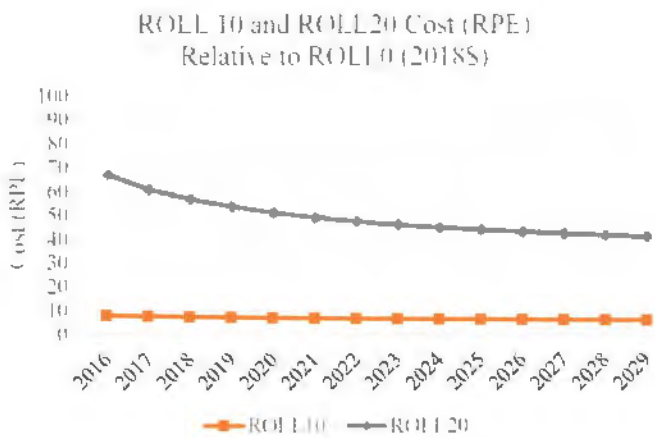

Figure VI-29 - Cost (RPE) for ROLL10 and ROLL20 Relative to ROLL0 in 2018$

7. Other Vehicle Technologies

Four other vehicle technologies were included in the analysis—electric power steering (EPS), improved accessory devices (IACC), low drag brakes (LDB), and secondary axle disconnect (SAX) (which may only be applied to vehicles with all-wheel-drive or four-wheel-drive). The effectiveness of these technologies was applied directly by the CAFE model, with unique effectiveness values for each technology and for each technology class. This methodology was used in these four cases because the effectiveness of these technologies varies little with combinations of other technologies. Also, applying these technologies directly in the CAFE model significantly reduces the number of Autonomie simulations that are needed.

a) Electric Power Steering (EPS)

Electric power steering reduces fuel consumption and CO_2 emissions by reducing load on the engine. Specifically, it reduces or eliminates the parasitic losses associated with engine-

driven power steering pumps, which pump hydraulic fluid continuously through the steering actuation system even when no steering input is present. By selectively powering the electric assist only when steering input is applied, the power consumption of the system is reduced in comparison to the traditional "always-on" hydraulic steering system. Power steering may be electrified on light duty vehicles with standard 12V electrical systems and is also an enabler for vehicle electrification because it provides power steering when the engine is off (or when no combustion engine is present).

Power steering systems can be electrified in two ways. Manufacturers may choose to eliminate the hydraulic portion of the steering system and provide electric-only power steering (EPS) driven by an independent electric motor, or they may choose to move the hydraulic pump from a belt-driven configuration to a stand-alone electrically driven hydraulic pump. The latter system is commonly referred to as electro-hydraulic power steering (EHPS). As discussed in the NPRM, manufacturers have informed the agencies that full EPS systems are being developed for all types of light-duty vehicles, including large trucks.

EPS is also discussed in [reference the Electrification Modeling in the CAFE model].

b) Improved Accessories (IACC)

Engine accessories typically include the alternator, coolant pump, cooling fan, and oil pump, and are traditionally mechanically-driven via belts, gears, or directly by other rotating engine components such as camshafts or the crankshaft. These can be replaced with improved accessories (IACC) which may include high efficiency alternators, electrically driven (i.e., on-demand) coolant pumps, electric cooling fans, variable geometry oil pumps, and a mild regeneration strategy.[1051] Replacing lower-efficiency and/or mechanically-driven components with these improved accessories results in a reduction in fuel consumption, as the improved accessories can conserve energy by being turned on/off "on demand" in some cases, driven at partial load as needed, or by operating more efficiently.

For example, electric coolant pumps and electric powertrain cooling fans provide better control of engine cooling. Flow from an electric coolant pump can be varied, and the cooling fan can be shut off during engine warm-up or cold ambient temperature conditions, reducing warm-up time, fuel enrichment requirements, and, ultimately reducing parasitic losses.

IACC is also discussed in [reference the Electrification Modeling in the CAFE model].

c) Low Drag Brakes (LDB)

Low or zero drag brakes reduce or eliminate brake drag force by separating the brake pad from the rotor, either by mechanical or electric methods. Conventional disc brake systems are designed such that the brake pad is in contact with the brake rotor at all times. This is true even

[1051] IACC in this analysis excludes other electrical accessories such as electric oil pumps and electrically driven air conditioner compressors.

when the brakes are not being applied, and although the contact pressure is light in this case, this still produces some drag force on the vehicle.

LDBs have historically employed a caliper and rotor system that allows the piston in the caliper to retract,[1052] in turn pulling the brake pads away from the rotor. However, if pads are allowed to move too far away from the rotor, the first pedal application made by the vehicle operator can feel spongy and have excessive travel. This can lead to customer dissatisfaction regarding braking performance and pedal feel. For this reason, in conventional hydraulic-only brake systems, manufacturers are limited by how much they can allow pads to move away from the rotor.

Recent developments in braking systems have resulted in brakes with the potential for zero drag. In these systems, the pedal feel is separated from hydraulics by a pedal simulator. This system is similar to the brake systems designed for hybrid and electric vehicles, where some of the primary braking is done through the recuperation of kinetic energy in the drive system. However, the pedal feel and the deceleration the operator experiences is tuned to provide a braking experience equivalent to that of a conventional hydraulic brake system. These "brake-by-wire" systems have highly tuned pedal simulators that feel like typical hydraulic brakes and seamlessly transition to a conventional system as required by different braking conditions. The application of a pedal simulator and brake-by-wire system is new to non-electrified vehicle applications. By using this type of system, vehicle manufacturers can allow brake pads to move farther away from the rotor and still maintain the initial pedal feel and deceleration associated with a conventional brake system.

In addition to reducing brake drag, the zero drag brake system provides ancillary benefits. It allows for a faster brake application and greater deceleration than is normally applied by the average vehicle operator. It also allows manufacturers to tune the braking for different customer preferences within the same vehicle. This means manufacturers can provide a "sport" mode, which provides greater deceleration with less pedal displacement and a "normal" mode, which might be more appropriate for day-to-day driving.

The zero drag brake system also eliminates the need for a brake booster. This saves cost and weight in the system. Elimination of the conventional vacuum brake booster could also improve the effectiveness of stop-start systems. Typical stop-start systems need to restart the engine if the brake pedal is cycled because the action drains the vacuum stored in the booster. Because the zero drag brake system provides braking assistance electrically, there is no need to supplement lost vacuum during an engine off event.

Finally, many engine technologies being considered to improve efficiency also reduce pumping losses through reduced throttling, and in turn there is less engine vacuum available to power-assist a conventional brake system. The reduction in throttling could require a supplemental vacuum pump to provide vacuum for a conventional brake system. This is the situation in many diesel-powered vehicles. Diesel engines have no throttling and require a

[1052] The brake caliper pistons are used to push the brake pad against the brake rotor, or disc.

supplemental vacuum for conventional brake systems. A zero drag brake system both eliminates brake drag and avoids the need for a supplemental vacuum pump.

d) Secondary Axle Disconnect (SAX)

All-wheel drive (AWD) and four-wheel drive (4WD) vehicles provide improved traction by delivering torque to the front and rear axles, rather than just one axle. When a second axle is rotating, it tends to consume more energy because of additional losses related to lubricant churning, seal friction, bearing friction, and gear train inefficiencies.[1053][1054] Some of these losses may be reduced by providing a secondary axle disconnect function that disconnects one of the axles when driving conditions do not call for torque to be delivered to both.

The terms AWD and 4WD are often used interchangeably, although they have also developed a colloquial distinction, and are two separate systems. The term AWD has come to be associated with light-duty passenger vehicles providing variable operation of one or both axles on ordinary roads. The term 4WD is often associated with larger truck-based vehicle platforms providing a locked driveline configuration and/or a low range gearing meant primarily for off-road use.

Many 4WD vehicles provide for a single-axle (or two-wheel) drive mode that may be manually selected by the user. In this mode, a primary axle (usually the rear axle) will be powered, while the other axle (known as the secondary axle) is not. However, even though the secondary axle and associated driveline components are not receiving engine power, they are still connected to the non-driven wheels and will rotate when the vehicle is in motion. This unnecessary rotation consumes energy,[1055] and leads to increased fuel consumption and CO_2 emissions that could be avoided if the secondary axle components were completely disconnected aud not rotating.

Light-duty AWD systems are often designed to divide variably torque between the front and rear axles in normal driving to optimize traction and handling in response to driving conditions. However, even when the secondary axle is not necessary for enhanced traction or handling, in traditional AWD systems it typically remains engaged with the driveline and continues to generate losses that could be avoided if the axle was instead disconnected. The SAX technology observed in the marketplace disengages one axle (typically the rear axle) for 2WD operation, but detects changes in driving conditious and automatically engages AWD mode when it is necessary. The operation in 2WD can result in reduced fuel consumption. For

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[1053] Phelps, P. "*EcoTrac Disconnecting AWD System*," presented at 7th International CTI Symposium North America
2013, Rochester MI.

[1054] Pilot Systems, "AWD Component Analysis," Project Report, performed for Transport Canada, Contract T8080-150132, May 31, 2016.

[1055] Any time a drivetrain component spins it consumes some energy, primarily to overcome frictional forces.

example, Chrysler has estimated the secondary axle disconnect feature in the Jeep Cherokee reduces friction and drag attributable to the secondary axle by 80% when in disconnect mode.[1056]

e) Analysis Fleet Assignments for Other Vehicle Technologies

The agencies described in the PRIA that the aforementioned technologies have been applied, to some extent, in the MY 2016 fleet. However, these technologies are difficult to observe and assign to the analysis fleet, and the agencies relied heavily on industry engagement and feedback to assign the technologies properly to the NPRM analysis fleet vehicles. In the NPRM, the agencies noted that the Draft TAR analysis did not properly account for the presence of these technologies in the analysis fleet, and far too few were assigned. Accordingly, the NPRM analysis reflected higher EPS and IACC application rates than the Draft TAR analysis.

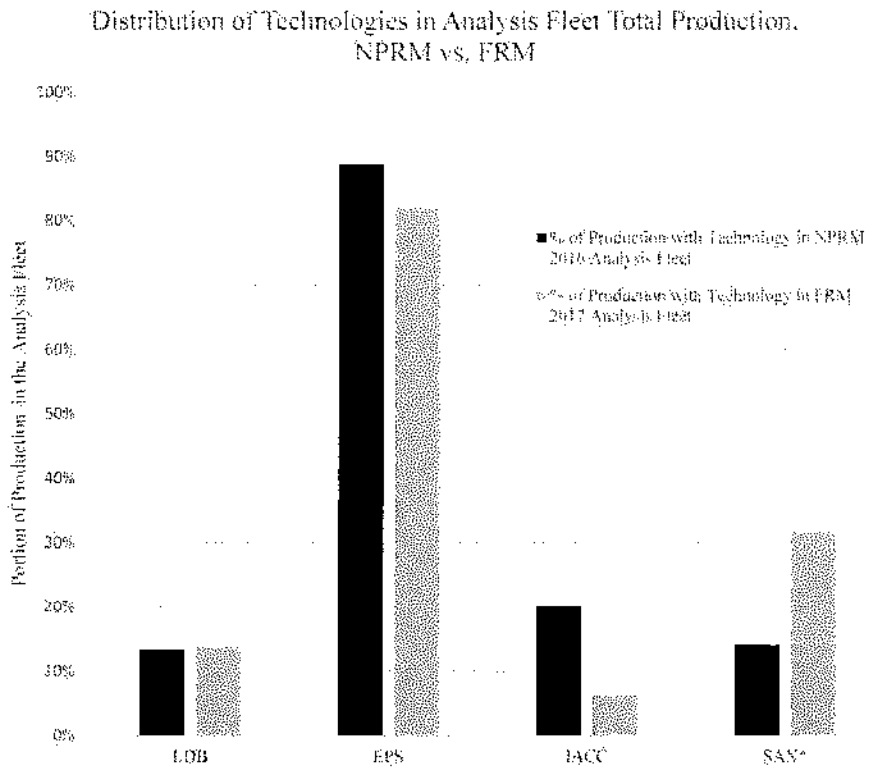
The agencies received a handful of comments stating that the additional technologies were incorrectly applied to the analysis fleet. ICCT stated that the inclusion of EPS, IACC, and LDB in the analysis fleet was unsubstantiated, and removed the technologies from potential use during the subsequent simulated years.[1057] ACEEE commented that IACC should not have been applied to certain vehicles in the analysis fleet because those vehicles do not in actuality display the fuel consumption reduction that would confirm the presence of these additional technologies.[1058] ACEEE additionally commented that the CAFE model assumes significant baseline SAX penetration that they could not corroborate from Ford F-150 product information brochures.[1059] HDS compared the available levels of IACC improvements from the Draft TAR to the NPRM analysis, noting that the NPRM only employed one level of improved accessory technologies.[1060] HDS stated that this implied the effectiveness of what was previously considered IACC1 (the first level of IACC technology improvement available in the Draft TAR) was completely used up in the 2016 analysis fleet for this rule.

As the agencies stated in the PRIA, in part because of the difficulty in observing EPS, IACC, LDB, and SAX on actual vehicles, far too few of those technologies were assigned to vehicles in the Draft TAR analysis fleets. For the final rule, each vehicle in the MY 2017 analysis fleet was studied using confidential and publicly available information to determine whether, as commenters suggested, the agencies had improperly applied any of these additional vehicle technologies. This resulted in some adjustments in the application of the technologies in the analysis fleet. In regard to ACEEE's comment on SAX penetration in the analysis fleet, for the NPRM and final rule analysis, the agencies considered all 4WD vehicles to have the capability manually to disconnect either the front or rear wheel axle and associated rotating components, thus shifting to a 2WD mode. When 4WD operation is required for safety and utility, the consumer can enable this feature. As stated above, this capacity to shift between 2WD and 4WD modes is another form of SAX. For AWD vehicles, publicly available

[1056] Brooke, L. "Systems Engineering a new 4x4 benchmark," *SAE Automotive Engineering*, June 2, 2014.
[1057] International Council on Clean Transportation, Attachment 3, Docket No. NHTSA-2018-0067-11741, at 1-37.
[1058] American Council for an Energy-Efficient Economy, Attachment 6, Docket No. NHTSA-2018-0067-12122, at 6.
[1059] American Council for an Energy-Efficient Economy, Attachment 6, Docket No. NHTSA-2018-0067-12122, at 7.
[1060] H-D Systems, "HDS final report", Docket No. NHTSA-2018-0067-11985, at 21.

manufacturer information was reviewed to identify the specific vehicles that have SAX technology. Based on market observations and feedback from OEMs, the entire analysis fleet for NPRM and the final rule was considered to have a basic level of improved accessories (comparable to what Draft TAR referred to as IACC1). The application of IACC in the NPRM and final rule analysis fleets represents further improvements to accessories such as electric water pumps and higher efficiency alternators with mild regeneration capacity.

The following distribution of technologies in the analysis fleet from the NPRM to the final rule analysis shows a slight decrease in the portion of total vehicles produced that have EPS and IACC, a very slight increase in the portion of total vehicle production that have LDB, and a slight increase in the portion of 4WD/AWD vehicles with SAX technology.



*Reflects the portion of 4WD/AWD vehicle production with SAX technology

Figure VI-30 - Distribution of Technologies in Analysis Fleet Production

f) Effectiveness Estimates for Other Vehicle Technologies

The effectiveness estimates for these four technologies rely on previous work published as part of the rulemaking process, both for the 2012 rule for MYs 2017-2025 and the Draft TAR. The effectiveness values are unchanged from the Draft TAR.

The effectiveness of both EPS and EHPS is derived from the decoupling of the pump from the crankshaft, and is considered to be practically the same for both. Thus, a single effectiveness value is assigned to all vehicles in the analysis fleet that possess either EPS or EHPS, and the "EPS" designation is applied.

For the Draft TAR analysis, two levels of IACC were offered as a technology path (a low improvement level and a high improvement level). Since much of the market has incorporated some of these technologies in the baseline MY 2016 and 2017 fleets, the NPRM and final rule analyses assumed all vehicles have incorporated what was previously the low level, so only the high level remained as an option for vehicles. The figure above shows the distribution of IACC for NPRM and FRM, which is the equivalent type of technology as the high-level IACC in the DRAFT TAR.

The NPRM analysis carried forward work on the effectiveness of SAX systems conducted in the Draft TAR and EPA Proposed Determination. This work involved gathering information by monitoring press reports, holding meetings with suppliers and OEMs, and attending industry technical conferences. The resulting effectiveness estimates used in the Draft TAR, NPRM, and this final rule are shown below.

Table VI-79 - Fuel Consumption Improvement Values for Other Vehicle Technologies

NPRM / Final Rule Fuel Consumption Improvements				
Tech Class	**LDB**	**EPS**	**IACC**	**SAX**
SmallCar	0.80%	1.50%	1.85%	1.40%
SmallCarPerf				
MedCar	0.80%	1.30%	2.36%	1.40%
MedCarPerf				
SmallSUV	0.80%	1.20%	1.74%	1.40%
SmallSUVPerf				
MedSUV	0.80%	1.00%	2.34%	1.30%
MedSUVPerf				
Pickup	0.80%	0.80%	2.15%	1.60%
PickupHT				

g) Cost Estimates and Learning Rates for Other Vehicle Technologies

The cost estimates for these technologies rely on previous work published as part of the rulemaking process, both for the 2012 rule for MYs 2017-2027 and the Draft TAR. The cost values are from the same sources as the Draft TAR and were updated to 2016 dollars for the NPRM and 2018 dollars for the final rule analysis.

CARB noted that the IACC costs in tables 6-32 and 6-33 of the PRIA did not align with the Technologies central analysis input file.[1061] HDS commented, as part of its comparison of IACC penetration in the analysis fleet from the Draft TAR to NPRM, that IACC costs were based on the difference between IACC1 and IACC2 costs and this appeared to be inconsistent with the cost of accessory electrification which is more expensive.[1062]

In the PRIA, the cost of IACC was reported in some tables as an absolute cost (the cost of adding IACC to a base vehicle), while the NPRM Technologies central analysis input file showed IACC cost incremental to EPS. This was necessary in the model input file because the accounting method of the NPRM CAFE model utilized incremental costs. In contrast, a change in the CAFE model accounting method for this final rule allows all costs in the input file to be reported as absolute costs, incremental to a base vehicle. It was assumed that EPS must be present on a vehicle in order for it to adopt IACC, and as such the cost of IACC includes the cost of EPS. For further detail on the use of absolute costs in place of incremental costs, see Section [ref section# on absolute cost accounting]. Although HDS commented that accessory electrification has a higher cost than what is being used in the analysis, no specific additional

[1061] CARB, Docket No. NHTSA-2018-0067-12428, at 21.
[1062] H-D Systems, "HDS final report", Docket No. NHTSA-2018-0067-11985, at 21.

input was given; the cost of IACC, as was done for Draft TAR (where it was referred to as IACC2), was taken from the 2015 NAS Report.[1063]

The table below shows the absolute costs for these technologies for select model years. The FRM Technologies central analysis input file shows the costs for all model years.

Table VI-80 – Final Rule Absolute Costs for Other Vehicle Technologies, including Learning Effects and Retail Price Equivalent (2018$)

Technology	2017	2021	2025	2029
EPS	$133.23	$124.42	$117.28	$111.97
IACC	$196.39	$163.40	$146.67	$136.96
LDB	$92.08	$84.60	$78.35	$73.97
SAX	$97.41	$86.69	$80.34	$75.98

Table VI-81Table VI-81 below shows the cost learning rates for the additional technologies used for both the NPRM and final rule analyses.

Table VI-81 - Learning Rates for Other Vehicle Technologies for MY 2016 to MY 2032

Technology	Model Years																
	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
EPS	0.94	0.93	0.91	0.89	0.88	0.86	0.85	0.84	0.82	0.81	0.8	0.79	0.78	0.77	0.77	0.76	0.75
IACC	1	0.93	0.88	0.83	0.79	0.76	0.73	0.71	0.69	0.67	0.66	0.64	0.63	0.62	0.61	0.6	0.6
LDB	0.94	0.93	0.91	0.89	0.87	0.85	0.84	0.82	0.8	0.79	0.77	0.76	0.75	0.74	0.73	0.72	0.72
SAX	0.77	0.73	0.7	0.67	0.65	0.64	0.62	0.61	0.6	0.59	0.58	0.57	0.56	0.55	0.54	0.54	0.53

8. Simulating Off-Cycle and A/C Efficiency Technology Adjustments

Off-cycle and air conditioning (A/C) efficiency technologies can provide fuel economy improvements in real-world vehicle operation, but that benefit cannot be adequately captured by the 2-cycle test procedures used to demonstrate compliance with fuel economy and CO_2 emissions standards.[1064] Off-cycle technologies include technologies like high efficiency

[1063] National Research Council. 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, DC – The National Academies Press. Table 8A.2a, available at. *https://www.nap.edu/catalog/21744/cost-effectiveness-and-deployment-of-fuel-economy-technologies-for-light-duty-vehicles.*

[1064] *See* 49 U.S.C 32904(c) ("The Administrator shall measure fuel economy for each model and calculate average fuel economy for a manufacturer under testing and calculation procedures prescribed by the Administrator. . . . the Administrator shall use the same procedures for passenger automobiles the Administrator used for model year 1975 (weighted 55 percent urban cycle and 45 percent highway cycle), or procedures that give comparable results.").

alternators and high efficiency exterior lighting.[1065] A/C efficiency technologies operate mainly by reducing the operation of the compressor, which pumps A/C refrigerant around the system loop. The less the compressor operates or the more efficiently it operates, the less load the compressor places on the engine, resulting in better fuel efficiency and lower CO_2 emissions.

Vehicle manufacturers have the option to generate credits for off-cycle technologies and improved A/C systems under the EPA's CO_2 program and receive a fuel consumption improvement value (FCIV) equal to the value of the benefit not captured on the 2-cycle test under NHTSA's CAFE program.[1066] The FCIV is not a credit in the NHTSA CAFE program, but the FCIVs increase the reported fuel economy of a manufacturer's fleet, which is used to determine compliance. EPA applies FCIVs during determination of a fleet's final average fuel economy reported to NHTSA.[1067] FCIVs are only calculated and applied at a fleet level for a manufacturer and are based on the volume of the manufacturer's fleet that contain qualifying technologies.[1068]

As discussed further in Section [P09], three pathways can be used to determine the value of A/C efficiency and off-cycle adjustments. First, manufacturers can use a predetermined list or "menu" of credit values established by EPA for specific off-cycle technologies.[1069] Second, manufacturers can use 5-cycle testing to demonstrate and justify off-cycle CO_2 credits;[1070] the additional tests allow emission benefits to be demonstrated over some elements of real-world driving not captured by the 2-cycle compliance tests, including high speeds, rapid accelerations, and cold temperatures. Third, manufacturers can seek EPA approval, through a notice and comment process, to use an alternative methodology other than the menu or 5-cycle methodology for determining the off-cycle technology improvement values.[1071]

The agencies have been collecting data on the application of these technologies since implementing the programs.[1072] Most manufacturers are generating A/C efficiency and off-cycle

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[1065] *See* 83 FR 43057. A partial list of off-cycle technologies is included in Tables II-21 and II-22 of the NPRM.
[1066] 77 FR 62624, 62720 (Oct. 15, 2012).
[1067] 49 U.S.C. 32904(c)-(e). EPCA granted EPA authority to establish fuel economy testing and calculation procedures. *See* Section [Section P09] for more information.
[1068] [Reference for how off-cycle credits are calculated]
[1069] *See* 40 CFR 86.1869-12(b). The Technical Support Document (TSD) for the 2012 final rule for MYs 2017 and beyond provides technology examples and guidance with respect to the potential pathways to achieve the desired physical impact of a specific off-cycle technology from the menu and provides the foundation for the analysis justifying the credits provided by the menu. The expectation is that manufacturers will use the information in the TSD to design and implement off-cycle technologies that meet or exceed those expectations in order to achieve the real-world benefits of off-cycle technologies from the menu.
[1070] *See* 40 CFR 86.1869-12(c). EPA proposed a correction for the 5-cycle pathway in a separate technical amendments rulemaking. *See* 83 FR 49344 (Oct. 1, 2019). EPA is not approving credits based on the 5-cycle pathway pending the finalization of the technical amendments rule.
[1071] *See* 40 CFR 86.1869-12(d).
[1072] *See* 77 FR at 62832, 62839 (Oct. 15, 2012). EPA introduced A/C and off-cycle technology credits for the CO_2 program in the MYs 2012-2016 rule and revised the program in the MY 2017-2025 rule and NHTSA adopted equivalent provisions for MYs 2017 and later in the MY 2017-2025 rule.

credits; in MY 2017, 15 manufacturers generated A/C efficiency credits and 15 manufacturers generated off-cycle credits, through the level of deployment varies by manufacturer.[1073]

a) A/C and Off-Cycle Effectiveness Modeling

The NPRM analysis used the off-cycle FCIVs and credits earned by each manufacturer in MY 2016 and carried these forward at the same levels for future years for the CO_2 analysis and beginning in MY 2017 for the CAFE analysis. The 2016 values for off-cycle FCIVs for each manufacturer and fleet, denominated in grams CO_2 per mile,[1074] are provided in Table VI-82Table VI-82.[1075] Additional off-cycle FCIVs were added in future years if a manufacturer applied a technology that was explicitly simulated in the analysis and also was an off-cycle technology listed on the predefined menu.[1076] Technologies explicitly simulated in the analysis that are also on the off-cycle menu include start-stop systems that reduce fuel consumption during idle and active grille shutters that improve aerodynamic drag at highway speeds, among others. Any off-cycle adjustments that accrued as the result of applying these technologies were calculated dynamically in each model year the technology was applied, with adjustments accumulating up to the 10 g/mi cap. As a practical matter, most of the adjustments for which manufacturers can claim off-cycle FCIVs exist outside of the CAFE model technology tree so the off-cycle menu cap was rarely reached for the NPRM analysis.

The agencies sought comment on both the A/C and off-cycle data that was used for the NPRM analysis as well as the assumptions for applying those technologies.

[1073] The 2018 EPA Automotive Trends Report, EPA-420-R-19-002, March 2019 at Chapter 5.B., Figures 5.10 and 5.11.

[1074] For the purpose of estimating their contribution to CAFE compliance, the grams CO_2/mile values in Table VI-82Table VI-82 are converted to gallons/mile and applied to a manufacturer's 2-cycle CAFE performance. When calculating compliance with EPA's CO_2 program, there is no conversion necessary (as standards are also denominated in grams/mile).

[1075] 2016 GHG Manufacturer Performance Report. EPA-420-R-18-002. January 2018. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100TGIA.pdf. Last Accessed Nov. 14, 2019.
2016 Report Tables for the GHG Manufacturer Performance Report. January 2018. https://www.epa.gov/sites/production/files/2018-01/ghg-report-2016-data-tables.xlsx. Last Accessed Nov. 14, 2019.

[1076] For more details, see Section [P09 Compliance subsection that discusses the menu].

Table VI-82 - NPRM Base Off-Cycle CO_2 Adjustments for MY 2016 and Later Model Years[1077]

Manufacturer	Off-Cycle Adjustment per Vehicle (g CO_2/mile)	
	PC	LT
BMW	1.70	2.60
Daimler	1.60	0.50
FCA	2.90	7.30
Ford	1.80	3.40
General Motors	2.20	4.00
Honda	1.90	1.60
Hyundai Kia-H	0.90	5.00
Hyundai Kia-K	1.00	3.00
JLR	0.50	4.20
Mazda	-	-
Nissan Mitsubishi	1.90	3.00
SUBARU	-	-
Tesla	-	-
TOYOTA	0.60	2.80
Volvo	-	-
VWA	-	-

Universally, stakeholders believed the application of off-cycle adjustments in the analysis was too conservative. Stakeholders believed the A/C and off-cycle technologies would be rapidly deployed and manufacturers would reach the cap values within the rulemaking timeframe.

The Institute for Policy Integrity (IPI) questioned the position the agencies assumed in the NPRM analysis, and suggested the agencies "assume that manufacturers will efficiently deploy all cost-saving offset opportunities, especially in the face of increasingly stringent standards."[1078]

ICCT stated "far greater use of the off-cycle provisions will occur by 2025" and emphasized that off-cycle technologies are "highly cost-effective and being deployed in greater

[1077] *See* 83 FR 43159-60 ("...this analysis uses the off-cycle credits submitted by each manufacturer for MY 2017 compliance and carries these forward to future years with a few exceptions.").
[1078] Comments from Institute from Policy Integrity, Attachment 1, NPRM Docket No. NHTSA-2018-0067-12213, at 20-21.

sales penetrations than many of the test-cycle efficiency technologies that the agencies are analyzing."[1079] ICCT supported manufacturers maximizing the use of off-cycle technologies, and supported the analysis estimating "fleetwide off-cycle credit use at over 10 g/mile by 2020," and further suggested fleetwide achievement of 15 g/mile by 2025.[1080]

FCA, General Motors and the Auto Alliance all provided similar observations, stating "[m]anufacturers have rapidly deployed technology in response to this all new regulatory mechanism." Each of the commenters provided support for an argument of rapid off-cycle technology adoption, stating "[i]n the MY2021-2026 timeframe of the proposed rule, it is likely that manufacturers will hit the existing 10 g/mi cap."[1081]

The DENSO Corporation further supported the increased use of off-cycle technologies, commenting that "[a]vailable data on OEM off-cycle technology credit utilization within the past few years demonstrates that the use of off-cycle technologies is expected to grow—particularly technologies on the credit menus."[1082]

However, Toyota Motors North America asked for constraints on considerations of off-cycle technology in the analysis.[1083] Toyota expressed concern for over-reliance on off-cycle technologies to provide flexibilities for compliance, as "most of the technologies provide little tangible value proposition for customers." In additional comments, Toyota repeated the concern noting, "most of these technologies lack consumer demand." Finally, Toyota specifically cautioned against overusing off-cycle technologies in the analysis, stating "[t]he suggested pursuit of maximum credits overlooks the associated costs and market acceptance challenge for certain off-cycle technologies." Toyota listed costs versus risk of customer acceptance and agency approval as factors that "introduce a high level of uncertainty for an auto manufacturer's planning and make investments in off-cycle technologies risky and less appealing."

After carefully considering the comments, the agencies agree that A/C and off-cycle technologies are likely to be more broadly applied by manufacturers within the rulemaking timeframe. The final rule analysis has been updated to reflect an increased application of the technologies. Similar to the NPRM, the final rule analysis used the A/C and off-cycle FCIVs earned by each manufacturer in the baseline fleet (MY 2017 for the final rule analysis) as a

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[1079] Comments from ICCT, Attachment 1, NPRM Docket No. NHTSA-2018-0067-11741, at 140 – 141.
[1080] Note there is a regulatory "cap" on menu technologies of 10 g/mi (see [Section P09] for further discussion of the cap), however a manufacturer can receive additional off-cycle credit/FCIV by using the pathways described above to petition for off-menu technologies. ICCT's comment suggests that manufacturers will reach the regulatory menu cap and apply additional technologies to get an additional 5 g/mi credit above the menu cap.
[1081] Comments from Automotive Alliance, Appendix 1, NPRM Docket No. NHTSA-2018-0067-12073, at 92; Comments from Fiat Chrysler Automobiles, Attachment1, NPRM Docket No. NHTSA-2018-0067-11943, at 8; Comments from General Motors, Appendix 4 – Comments to Technical Issues, NPRM Docket No. NHTSA-2018-0067-11858, at 1.
[1082] Comments from DENSO Corporation, Attachment 1, NPRM Docket No. NHTSA-2018-0067-11880, at 6.
[1083] Comments from Toyota Motors North America, Attachment 1, NHTSA Docket No. NHTSA-2018-0067-130798, at 9-10; Supplemental Comments from Toyota Motors North America, Attachment 1, NHTSA Docket No. NHTSA-2018-0067-12150, at 24; Supplemental Comments from Toyota Motors North America, Attachment 1, NHTSA Docket No. NHTSA-2018-0067-12376, at 4-5.

starting point. However, the final rule analysis increased these values in subsequent model years. In addition to the dynamic application of off-cycle FCIVs, as in the NPRM, each manufacturer's fleet FCIVs were increased by extrapolating the manufacturers' historical rate of FCIV application through 2017.[1084] In line with most commenters, the agencies increased the FCIVs for each manufacturer such that the maximum value of 10 g/mi will be reached by MY 2023. For manufacturers who did not reach maximum values prior to 2023 through data extrapolation, a linear increase to the cap was assumed. The agencies believe this approach balances a greater application of FCIV technologies across the fleet, while avoiding uncertain over-reliance on flexibilities for the analysis.

The agencies disagreed with the proposal to model the application of 15 g/mi of FCIVs universally in the rulemaking timeframe. Based on historical data and industry comments from both manufacturers and suppliers, the agencies expect there will be an increase in off-cycle technology application. However, there are two issues with assuming manufacturers will exceed the existing off-cycle caps. First, only a few manufacturers approached the cap limit in MY 2018, and the fleet average menu credit was 4.7 grams/mile, less than half the cap value.[1085] Second, new off-cycle technologies may address the same inefficiencies as menu technologies, rather than work in conjunction. Accordingly, the agencies believe there is a reasonable basis for assuming manufacturers could, and would only achieve 10 g/mi on average by MY 2023, and used that assumption for the final rule analysis.

Table VI-83 shows passenger car values for FCIVs and Table VI-84 shows light truck values for FCIVs applied for the final rule analysis.

Table VI-83 -Passenger Car Base A/C and Off-Cycle CO_2 Improvement Values per Vehicle for Manufacturers by Model Year for the Final Rule Analysis (g CO_2/mile)

Manufacturer	Passenger Car						
	2017	2018	2019	2020	2021	2022	2023
BMW							
AC Efficiency	4.7	4.7	4.8	4.8	4.9	4.9	5.0
AC Leakage	13.7	13.7	13.7	13.8	13.8	13.8	13.8
Off-Cycle	3.5	4.6	5.6	6.7	7.8	8.9	10.0
FFV Credits	-	-	-				
Daimler							
AC Efficiency	4.9	5.0	5.0	5.0	5.0	5.0	5.0
AC Leakage	6.0	7.3	8.6	9.9	11.2	12.5	13.8
Off-Cycle	1.1	2.6	4.1	5.6	7.0	8.5	10.0
FFV Credits	0.6	0.4	0.2				
FCA							

[1084] The 2018 EPA Automotive Trends Report, https://www.epa.gov/fuel-economy-trends/download-report-co2-and-fuel-economy-trends. Accessed Aug 23, 2019.
[1085] The 2018 EPA Automotive Trends Report, Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975, EPA-420-R-19-002 (Mar. 2019).

AC Efficiency	4.2	4.4	4.5	4.6	4.7	4.9	5.0
AC Leakage	12.5	12.7	12.9	13.1	13.4	13.6	13.8
Off-Cycle	3.4	4.5	5.6	6.7	7.8	8.9	10.0
FFV Credits	0.6	0.4	0.2				
Ford							
AC Efficiency	3.3	3.6	3.9	4.2	4.4	4.7	5.0
AC Leakage	11.6	12.0	12.4	12.7	13.1	13.4	13.8
Off-Cycle	4.7	5.6	6.5	7.3	8.2	9.1	10.0
FFV Credits	0.6	0.4	0.2				
General Motors							
AC Efficiency	3.8	4.0	4.2	4.4	4.6	4.8	5.0
AC Leakage	9.1	9.9	10.7	11.5	12.2	13.0	13.8
Off-Cycle	5.3	6.1	6.8	7.6	8.4	9.2	10.0
FFV Credits	0.6	0.4	0.2				
Honda							
AC Efficiency	3.0	3.4	3.7	4.0	4.3	4.7	5.0
AC Leakage	7.4	8.5	9.6	10.6	11.7	12.7	13.8
Off-Cycle	2.0	3.3	4.7	6.0	7.3	8.7	10.0
FFV Credits	-	-	-				
Hyundai Kia-H							
AC Efficiency	3.4	3.7	3.9	4.2	4.5	4.7	5.0
AC Leakage	3.1	4.8	6.6	8.4	10.2	12.0	13.8
Off-Cycle	1.5	2.9	4.4	5.8	7.2	8.6	10.0
FFV Credits	-	-	-				
Hyundai Kia-K							
AC Efficiency	3.2	3.5	3.8	4.1	4.4	4.7	5.0
AC Leakage	7.1	8.2	9.3	10.4	11.6	12.7	13.8
Off-Cycle	2.0	3.3	4.7	6.0	7.3	8.7	10.0
FFV Credits	-	-	-				
JLR							
AC Efficiency	5.0	5.0	5.0	5.0	5.0	5.0	5.0
AC Leakage	13.8	13.8	13.8	13.8	13.8	13.8	13.8
Off-Cycle	5.6	6.3	7.1	7.8	8.5	9.3	10.0
FFV Credits	-	-	-				
Mazda							
AC Efficiency	-	0.8	1.7	2.5	3.3	4.2	5.0
AC Leakage	-	2.3	4.6	6.9	9.2	11.5	13.8
Off-Cycle	-	1.7	3.3	5.0	6.7	8.3	10.0
FFV Credits	-	-	-				
Mitsubishi							

AC Efficiency	2.9	3.3	3.6	4.0	4.3	4.7	5.0
AC Leakage	4.0	5.6	7.3	8.9	10.5	12.2	13.8
Off-Cycle	2.0	3.4	4.7	6.0	7.3	8.7	10.0
FFV Credits	-	-	-				
Nissan							
AC Efficiency	2.9	3.3	3.6	4.0	4.3	4.7	5.0
AC Leakage	4.0	5.6	7.3	8.9	10.5	12.2	13.8
Off-Cycle	2.0	3.4	4.7	6.0	7.3	8.7	10.0
FFV Credits	-						
Subaru							
AC Efficiency	2.5	2.9	3.4	3.8	4.2	4.6	5.0
AC Leakage	4.3	5.9	7.4	8.9	10.4	12.0	13.5
Off-Cycle	0.5	2.1	3.6	5.2	6.8	8.4	10.0
FFV Credits	-	-	-				
Tesla							
AC Efficiency	5.7	5.0	5.0	5.0	5.0	5.0	5.0
AC Leakage	-						
Off-Cycle	6.5	7.8	9.4	10.0	10.0	10.0	10.0
FFV Credits	-	-	-				
Toyota							
AC Efficiency	4.4	4.5	4.6	4.7	4.8	4.9	5.0
AC Leakage	3.2	5.0	6.8	8.5	10.3	12.0	13.8
Off-Cycle	3.6	4.6	5.7	6.8	7.9	8.9	10.0
FFV Credits	-	-	-				
Volvo							
AC Efficiency	4.0	4.2	4.3	4.5	4.7	4.8	5.0
AC Leakage	5.4	6.8	8.2	9.6	11.0	12.4	13.8
Off-Cycle	3.4	4.5	5.6	6.7	7.8	8.9	10.0
FFV Credits	-	-	-				
VWA							
AC Efficiency	3.9	4.1	4.3	4.5	4.6	4.8	5.0
AC Leakage	5.1	6.5	8.0	9.4	10.9	12.3	13.8
Off-Cycle	-	1.7	3.3	5.0	6.7	8.3	10.0
FFV Credits	-	-	-				

Table VI-84 - Light Truck Base A/C and Off-Cycle CO_2 Improvement Values per Vehicle for Manufacturers by Model Year for the Final Rule Analysis (g CO_2/mile)

Manufacturer	Light Truck						
	2017	2018	2019	2020	2021	2022	2023
BMW							
AC Efficiency	5.5	5.9	6.3	6.7	7.2	7.2	7.2

AC Leakage	16.8	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle	6.8	8.1	9.7	10.0	10.0	10.0	10.0
FFV Credits	-	-	-				
Daimler							
AC Efficiency	7.1	7.2	7.2	7.2	7.2	7.2	7.2
AC Leakage	6.7	8.4	10.2	11.9	13.7	15.4	17.2
Off-Cycle	2.4	3.6	4.9	6.2	7.5	8.7	10.0
FFV Credits	0.6	0.4	0.2				
FCA							
AC Efficiency	5.8	6.2	6.6	7.1	7.2	7.2	7.2
AC Leakage	15.8	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle	9.8	10.0	10.0	10.0	10.0	10.0	10.0
FFV Credits	0.6	0.4	0.2				
Ford							
AC Efficiency	5.6	6.0	6.4	6.8	7.2	7.2	7.2
AC Leakage	12.4	14.9	17.2	17.2	17.2	17.2	17.2
Off-Cycle	9.4	10.0	10.0	10.0	10.0	10.0	10.0
FFV Credits	0.6	0.4	0.2				
General Motors							
AC Efficiency	6.5	6.6	6.7	6.8	7.0	7.1	7.2
AC Leakage	14.7	15.1	15.5	15.9	16.4	16.8	17.2
Off-Cycle	7.7	9.2	10.0	10.0	10.0	10.0	10.0
FFV Credits	0.6	0.4	0.2				
Honda							
AC Efficiency	5.1	5.5	5.9	6.3	6.7	7.2	7.2
AC Leakage	14.1	16.9	17.2	17.2	17.2	17.2	17.2
Off-Cycle	5.5	6.6	7.9	9.5	10.0	10.0	10.0
FFV Credits	-	-	-				
Hyundai Kia-H							
AC Efficiency	5.4	5.7	6.0	6.3	6.6	6.9	7.2
AC Leakage	1.6	4.2	6.8	9.4	12.0	14.6	17.2
Off-Cycle	5.3	6.4	7.7	9.2	10.0	10.0	10.0
FFV Credits	-	-	-				
Hyundai Kia-K							
AC Efficiency	5.2	5.5	5.8	6.2	6.5	6.9	7.2
AC Leakage	6.7	8.4	10.2	11.9	13.7	15.4	17.2
Off-Cycle	3.2	4.4	5.5	6.6	7.7	8.9	10.0
FFV Credits	-	-	-				
JLR							
AC Efficiency	7.2	7.2	7.2	7.2	7.2	7.2	7.2

AC Leakage	17.2	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle	8.8	10.0	10.0	10.0	10.0	10.0	10.0
FFV Credits	-	-	-				
Mazda							
AC Efficiency	-	1.2	2.4	3.6	4.8	6.0	7.2
AC Leakage	-	2.9	5.7	8.6	11.5	14.3	17.2
Off-Cycle	-	1.7	3.3	5.0	6.7	8.3	10.0
FFV Credits	-	-	-				
Mitsubishi							
AC Efficiency	2.7	3.5	4.2	5.0	5.7	6.5	7.2
AC Leakage	6.4	8.2	10.0	11.8	13.6	15.4	17.2
Off-Cycle	4.5	5.4	6.3	7.2	8.2	9.1	10.0
FFV Credits	-	-	-				
Nissan							
AC Efficiency	2.7	3.5	4.2	5.0	5.7	6.5	7.2
AC Leakage	6.4	8.2	10.0	11.8	13.6	15.4	17.2
Off-Cycle	4.5	5.4	6.3	7.2	8.2	9.1	10.0
FFV Credits	-						
Subaru							
AC Efficiency	4.7	5.1	5.5	5.9	6.4	6.8	7.2
AC Leakage	7.0	8.7	10.4	12.1	13.8	15.5	17.2
Off-Cycle	0.5	2.0	3.6	5.2	6.8	8.4	10.0
FFV Credits	-	-	-				
Tesla							
AC Efficiency	-	-	-	-	-	-	-
AC Leakage	-	-	-	-	-	-	-
Off-Cycle	-	-	-	-	-	-	-
FFV Credits	-	-	-	-	-	-	-
Toyota							
AC Efficiency	5.4	5.7	6.0	6.3	6.6	6.9	7.2
AC Leakage	7.3	9.0	10.6	12.3	13.9	15.6	17.2
Off-Cycle	7.1	8.6	10.0	10.0	10.0	10.0	10.0
FFV Credits	0.6	0.4	0.2				
Volvo							
AC Efficiency	5.8	6.1	6.3	6.5	6.7	7.0	7.2
AC Leakage	7.0	8.7	10.4	12.1	13.8	15.5	17.2
Off-Cycle	5.6	6.3	7.0	7.8	8.5	9.3	10.0
FFV Credits	-	-	-				
VWA							
AC Efficiency	6.6	7.1	7.2	7.2	7.2	7.2	7.2

AC Leakage	6.2	8.0	9.9	11.7	13.5	15.4	17.2
Off-Cycle	-	1.7	3.3	5.0	6.7	8.3	10.0
FFV Credits	0.6	0.4	0.2				

b) A/C Efficiency, A/C Leakage and Off-Cycle Costs

As discussed above, the only A/C efficiency and off-cycle technologies applied dynamically in the NPRM analysis were explicitly simulated technologies like stop-start systems and active aerodynamic technologies. The NPRM analysis fully accounted for both the effectiveness and cost of these technologies and therefore separate cost accounting was not needed. For example, when stop-start or active aerodynamics technology was added by the model to a vehicle, the corresponding off-cycle FCIVs were applied and the technology costs were captured the same as every other technology on the decision trees.

For the final rule analysis, A/C and off-cycle technologies are applied independently of the decision trees using the extrapolated values, so it is necessary to account for the costs of those technologies independently. Table VI-85 shows the costs used for A/C and off-cycle FCIVs the final rule analysis. The costs are shown in dollars per gram of CO_2 per mile ($ per g/mile). The A/C costs and off-cycle technology costs are the same costs used in the EPA Proposed Determination and described in the EPA Proposed Determination TSD.[1086]

Table VI-85 - A/C and Off-Cycle FCIV Costs for this final rulemaking in dollars per gram of CO2 per mile ($2018)

Reg Class	2017	2018	2019	2020	2021	2022	2023
Passenger Car							
AC Efficiency Costs	4.57	4.48	4.39	4.30	4.22	4.13	4.05
AC Leakage Costs	11.43	11.20	10.97	10.76	10.54	10.33	10.12
Off-Cycle Costs	89.59	87.48	85.37	83.79	82.21	81.16	79.58
Light Truck							
AC Efficiency Costs	4.57	4.48	4.39	4.30	4.22	4.13	4.05
AC Leakage Costs	11.43	11.20	10.97	10.76	10.54	10.33	10.12
Off-Cycle Costs	89.6	87.48	85.37	83.79	82.21	81.16	79.58

[1086] EPA PD TSD. EPA-420-R-16-021. November 2016. At 2-423 – 2-245. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100Q3L4.pdf. Last accessed Nov.14, 2019.

D. Impacts that result from simulating manufacturer compliance with regulatory alternatives

1. Simulating economic impacts of regulatory alternatives

a) What economic impacts occur when vehicle manufacturers comply with different CAFE and CO_2 standards?

(1) The NPRM framework for analyzing economic impacts

In the proposed rule, the agencies noted the importance of identifying the mechanisms by which vehicle manufacturers' compliance with different CAFE and CO_2 standards generated impacts on manufacturers, owners of new and used vehicles, and the remainder of the U.S. The agencies organized the analysis of alternative standards using a framework that clarified the economic impacts on vehicle producers, illustrated how costs were transmitted to buyers of new vehicles, highlighted the collateral economic effects on owners of used vehicles, and identified how these responses created various indirect costs and benefits. Throughout the analysis, the agencies stressed the distinction between the proposal's economic consequences for private businesses and households, and its "external" economic impacts—those ultimately borne by the rest of the U.S. economy.

To clarify the framework used in the proposal, the agencies used Table VI-86Table VI-86 below (which is based on Tables II-25 to II-28 from the NPRM)[1087] to report costs and benefits and to trace how they pass through the economy. As the table shows, the economic impacts of standards initially fall on vehicle manufactures, but ultimately are borne by consumers who purchase and drive new models. Smaller, indirect economic effects of the proposal would be borne by owners of used cars and light trucks (vehicles produced during model years prior to those affected by the proposal, but still in use) as well as by the general public and government agencies. On balance, the agencies projected that most of the proposal's economic effects would fall on private businesses and households, with the remainder of the U.S. economy bearing much smaller impacts.

Table VI-86 - Benefits and Costs Resulting from Proposed CAFE Standards

Line	Affected Party	Source	Private Benefits and (Costs)
1	Vehicle Manufacturers	CAFE model	Savings in technology costs to increase fuel economy
2			Reduced fine payments for non-compliance
3		assumed = -(1+2)	Net loss in revenue from lower vehicle prices
4		net = 1+2+3	Net benefits to manufacturers
5		assumed = 3	Lower purchase prices for new vehicles

[1087] *See* 83 FR at 43062-66.

6	New Vehicle Buyers	CAFE model	Reduced injuries and fatalities from higher vehicle weight
7			Higher fuel costs from lower fuel economy (measured using retail fuel prices)
8			Inconvenience from more frequent refueling
9			Lost mobility benefits from reduced driving
10		net = 5+6+7+8+9	Net benefits to new vehicle buyers
11	Used Vehicle Owners	CAFE model	Reduced costs for injuries and property damage costs from driving in used vehicles
12	All Private Parties	net = 4+10+11	Net private benefits
Line	Affected Party	Source	External Benefits and (Costs)
13	Rest of U.S. Economy	CAFE Model	Increase in climate damages from added CO_2 Emissions
14			Increase in health damages from added emissions of air pollutants
15			Increase in economic externalities from added petroleum use
16			Reduction in civil penalty revenue
17			Reduction in external costs from lower vehicle use
18			Increase in Fuel Tax Revenues
19		net = 13+14+15+16+17+18	Net external benefits
Line	Affected Party	Source	Economy-Wide Benefits and (Costs)
20	Entire U.S. Economy	total = 1+2+5+6+11+17+18	Total benefits
21		total = 3+7+8+9+13+14+15+16	Total costs
22		net = 20+21 (also =12+19)	Net Benefits

More specifically, the agencies' analysis showed that the proposal would initially have saved manufacturers the costs of adding the technologies that would otherwise have been necessary to enable their new cars and light trucks to comply with the baseline fuel economy and CO_2 emissions regulations, with the estimated dollar value of those savings shown in line 1 of Table VI-86Table VI-86. The proposal also enabled some manufacturers to make lower civil penalty payments for failing to comply with the more demanding standards that were supplanted (line 2), although these savings would have been exactly offset by lower civil penalty revenue to the Federal Government (line 16). The analysis assumed that manufacturers would have the ability, in a competitive market, to pass their savings in technology costs and any reduction in civil penalties paid on to buyers, by charging lower prices for new vehicles. Although lower prices reduced their revenues (line 3), on balance, their savings in compliance costs, reduced civil penalty payments, and lower sales revenue were assumed to leave manufacturers financially unaffected (shown by the zero entry in line 4 of the table).

Under the proposal, the analysis showed that buyers of new cars and light trucks benefited directly from those vehicles' lower purchase prices and financing costs (line 5). They also avoided the increased risk of crash-related injuries that would have resulted from reductions in the weight of some new models, as manufacturers attempted to improve fuel economy to comply with the baseline standards. The economic value of this reduction in risk represented an additional benefit from the proposal to reducing the stringency of the standards vis-à-vis the baseline (line 6).

At the same time, however, the lower fuel economy that some new cars and light trucks were expected to offer with less stringent standards in place would have imposed various additional costs on their buyers and users. Drivers experienced higher fuel costs as a consequence of new vehicles' increased fuel consumption (line 7), as well as the added time and inconvenience of having to make more frequent refueling stops required by reduced driving range (line 8). They also forfeited some mobility benefits as they drove newly-purchased cars and light trucks less in response to their higher fuel costs (line 9). On balance, the agencies' analysis of the proposal showed that buyers of new cars and light trucks produced during the model years it affected would experience significant economic benefits (line 10).

A novel feature of the agencies' evaluation of the proposal showed that lowering prices for new cars and light trucks, some owners of used vehicles retired them from service earlier than they otherwise would have done. ~~In combination with increased sales of new models, this transferred some driving that would have occurred with used cars and light trucks to newer and safer models, thus reducing the total costs of fatalities and injuries sustained in motor vehicle crashes.~~[1088] ~~In the proposal, this reduction in injury risks provided benefits to owners and drivers of older cars and light trucks that had not been recognized or quantified in its analyses of previous CAFE and CO_2 standards (line 11).~~

Table VI-86Table VI-86also showed that the changes in fuel consumption and vehicle use resulting from the proposal would in turn generate both benefits and costs to the remainder of the U.S. economy. The analysis described these as "external" effects, in the sense that they were by-products of households' choices among new vehicle models, decisions about keeping older cars and light trucks in service, and allocations of driving across the fleet that were experienced broadly throughout the U.S. economy, rather than by the individuals making such decisions. The largest of these was additional refining and consumption of petroleum-based fuel and the associated increases in emissions of carbon dioxide and other gases, which were projected to increase the cost of economic damages inflicted on the U.S. economy by future changes in the global climate (line 13). Added fuel production and use under the proposal also led to higher emissions of localized air pollutants, and the resulting increase in the U.S. population's exposure and its adverse effects on health imposed additional external costs (line 14).

Increased consumption of petroleum-derived fuel also imposed higher external costs on the U.S. economy, in the form of potential losses in economic output and costs to businesses and

Commented [A261]: DELETE: While it may sound logical that the balance of driving would shift to newer vehicles with the final standards, this is not the case. The CAFE model shows that the average VMT-weighted age actually is higher (older) with the final standards.

This seemingly counter-intuitive result is due to the fact that the effect of the accelerated retirement of older vehicles is more than offset by the shift in driving towards more efficient (and typically newer, safer) vehicles due to the rebound effect.

Commented [A262]: DELETE: Similar to the comment above, the overall risk of driving is essentially unchanged (actually, slightly increased with the new standards over the accounting period) due to a change in the distribution of driving across vehicles with different risk.

[1088] ~~This improvement in safety resulted from the fact that cars and light trucks have become progressively more protective in crashes over time (and also slightly less prone to certain types of crashes, such as rollovers). Thus, shifting some travel from older to newer models reduced injuries and damages sustained by drivers and passengers because they were traveling in inherently safer vehicles, rather than because of changes to driver risk profiles.~~

households for adjusting to any sudden changes in energy prices (line 15 of the table). Reduced driving by buyers of new cars and light trucks in response to their higher operating costs also reduced the external costs from their contributions to traffic delays and noise, benefits that were expected to be experienced throughout the U.S. economy (line 17). Finally, some of the higher fuel costs to buyers of new cars and light trucks will consist of increased fuel taxes; this increase in revenue was projected to enable Federal and State government agencies to improve upkeep of roads and highways, fund increases in other services, or reduce other tax burdens (line 18).[1089]

The net economic effect (line 22) of the proposal consisted of the benefits and costs imposed directly on car and light truck manufacturers, accompanying indirect effects on buyers of new vehicles and owners of used ones, external costs driving decisions generated throughout the U.S. economy, and changes in revenue to government agencies. The agencies' organization was intended to convey the causal connections among these impacts, by highlighting how the proposed change in fuel economy standards faced by manufacturers would set in motion the sequence of behavioral responses that determined its economy-wide costs and benefits. ~~This contrasted with the way benefits and costs of previous proposals to establish CAFE and CO_2 standards were analyzed and presented, which obscured their sequence and causal connections.~~

Commented [A263]: DELETE: This is not true. Benefit-cost tables describe the impacts of the rule compared to a counterfactual. Previous presentations provided the same function.

Commented [A264]: REVISE: This seems like an odd use of the term co-benefits. Co-benefits are not about who gains & who loses, but rather about ancillary impacts.

In those previous analyses, most economic effects other than manufacturers' costs to comply with proposed standards and anticipated changes in fuel consumption were grouped together and reported as "co-benefits." This obscured how these various consequences arose from the proposed standards, providing no information about who would ultimately experience the costs of complying with the standards, or who would experience their direct and indirect benefits. In contrast, the recent analysis spelled out how each category of benefits and costs resulted from the proposed change in standards, identified the mechanisms that translated direct economic impacts into indirect costs and benefits, and distinguished between those arising from changes in fuel consumption, and safety consequences of changes in vehicle use. The proposal's framework also clarified who would bear each category of impacts, distinguishing between the proposal's economic impacts on private actors–vehicle manufacturers, new car and light truck buyers, and owners of used vehicles–and the external economic consequences for the general public and government agencies that stem indirectly from such private impacts.

(2) Final rule framework

While the agencies received several comments about which economic effects are included in the analysis, the agencies received no comments about the specific structure of the framework. Substantive comments about individual effects are addressed over the next several sections.

The agencies have expanded the accounting framework for benefits and costs shown in Table VI-86Table VI-86 above to include two additional entries, and distinguished financial impacts on government agencies from externalities borne broadly across the remainder of the U.S. economy. The revised accounting framework for costs and benefits is shown in Table

[1089] In some States, levies on gasoline include both general sales taxes as well as excise taxes, and not all proceeds are dedicated to transportation purposes.

VI-87Table VI-87, below. Line 6 of the revised table reports the change in consumer surplus experienced by buyers of new cars and light trucks when prices and sales of those vehicles adjust in response to changes in CAFE and CO_2 standards. The gain in consumer surplus that occurs when production costs and prices for vehicles fall and sales increase in response represents a benefit to buyers, while any loss in consumer surplus that occurs when more stringent standards increase costs and prices and cause sales to decline appears as a loss to new car and light truck buyers.

Commented [A265]: REVISE: I believe this is new since the NPRM, and thus has not received public comment. It's likely that VMT impacts already measure this gain, because the benefit of vehicle ownership is the mobility it provides. It may be double-counting to include benefits both for vehicle ownership & use.

Line 7 of Table VI-87Table VI-87 reports the estimated value of changes to attributes of new cars and light trucks other than fuel economy that their manufacturers make to comply with changes in CAFE and CO_2 standards. In the case where standards are less stringent, manufacturers are able to employ many of the same resources they would have deployed to increase fuel economy for the alternative purpose of improving other attributes of vehicles that their potential buyers value more highly than the forgone improvements in fuel economy. This response provides an additional benefit to purchasers of new cars and light trucks that was not recognized in the agencies' analysis of the proposal, but is included in the analysis of this final rule. Of course, if CAFE and CO_2 standards are made more stringent, manufacturers employ those technologies to increase fuel economy, thus sacrificing potential improvements in competing attributes—those that entail tradeoffs with higher fuel economy—and the value of improvements in those other attributes that is sacrificed or forgone represents an opportunity cost to those buyers. This implicit opportunity cost is analyzed in a sensitivity analysis and is not included in the primary analysis.

Finally, the agencies revised the framework for reporting costs and benefits of changes in CAFE and CO_2 standards to identify government agencies separately from the entry previously labeled "Rest of U.S Economy." This minor revision is intended to distinguish more clearly between changes in external costs imposed by externalities that result from fuel production and use, and the revenue effects on government agencies from changes in tax payments. While both effects ultimately result from manufacturers' compliance with revised standards and the resulting changes in fuel consumption, externalities represent real economic costs; in contrast, changes in tax revenues received by government agencies are financial transfers, whose offsetting effects on manufacturers and vehicle buyers are also recognized elsewhere in the accounting framework.

Table VI-87 - Benefits and Costs of Final CAFE and CO_2 Standards

Line	Affected Party	Source	Private Benefits and (Costs)
1	Vehicle Manufacturers	CAFE model	Savings in technology costs to increase fuel economy
2			Reduced fine payments for non-compliance
3		assumed = -(1+2)	Net loss in revenue from lower vehicle prices
4		net = 1+2+3	Net benefits to manufacturers
5	New Vehicle Buyers	assumed = 3	Lower purchase prices for new vehicles
6		CAFE model	Gain in consumer surplus from lower vehicle prices

7			~~Forgone Vehicle Attributes~~ Indirect Opportunity Costs (sensitivity analysis case only)
8			~~Reduced~~ Change in injuries and fatalities from higher vehicle weight
9			Higher fuel costs from lower fuel economy (measured using retail fuel prices)
10			Time and inconvenience from more frequent refueling
11			Loss in mobility benefits from reduced driving
12		net = 5+6+8+9+10+11	Net benefits to new vehicle buyers
13	Used Vehicle Owners	CAFE model	Reduced costs for injuries and property damage costs from driving in used vehicles
14	All Private Parties	net = 4+12+13	Net private benefits
15	Government agencies	CAFE Model	Reduction in revenue from civil penalties
16			Increase in fuel tax revenue
17		Net=15+16	Net effect on government agency revenue
18	Rest of U.S. Economy	CAFE Model	Increase in climate damages from added CO_2 Emissions
19			Increase in health damages from added emissions of air pollutants
20			Increase in economic externalities from added petroleum use
21			Reduction in external costs from lower vehicle use
22		net = 18+19+20+21	Net external benefits
23	Entire U.S. Economy	total = 1+2+5+6+8+13+16+21	Total benefits
24		total = 3+7+9+10+11+15+18+19+20	Total costs
25		net = 21+22 (also =14+17+22)	Net Benefits

Commented [A266]: CHANGE AS SHOWN: The table should use the same language that's used in the text.

Commented [A267]: CHANGE AS SHOWN: "reduced injuries and fatalities" is not correct as a general statement. The sign of the mass-safety coefficient (and therefore the directionality of the mass-safety effect) depends on the safety class (PC,LT,CM.)

Also, the mass safety effect is for societal safety, and would not belong only in the "New Vehicle Buyers" category.

b) Economic Assumptions

(1) Macroeconomic assumptions that affect the agencies' analysis

As the proposed rule noted, the more comprehensive economic impact analysis of CAFE and CO_2 included in this rulemaking requires a more detailed and explicit explanation of the macroeconomic context in which regulatory alternatives are evaluated. The agencies continued to rely on projections of future fuel prices to evaluate manufacturers' use of fuel-saving technologies, the resulting changes in fuel consumption, and various other benefits. Furthermore, the agencies expanded the scope of their analysis to include projecting future sales of new cars and light trucks as well as the retirement of used vehicles under each regulatory alternative. In addition to projections of future fuel prices, constructing these forecasts requires

explicit projections of macroeconomic variables, including U.S. Gross Domestic Product (GDP), labor force participation (the number of persons employed or actively seeking employment), and bellwether interest rates, which are likely to vary according to roughly the same pattern as interest rates on new car loans.

The analysis presented in the proposal as well as the accompanying RIA and EIS employed forecasts of future fuel prices developed by the agencies using the U.S. Energy Information Administration's (EIA's) National Energy Model System (NEMS). An agency within the U.S. Department of Energy (DOE), EIA collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment. EIA uses NEMS to produce its Annual Energy Outlook (AEO), which presents forecasts of future fuel prices, among many other energy-related variables. AEO projections of energy prices and other variables are not intended as predictions of what will happen; rather, they are projections of the likely course of these variables that reflect their past relationships, specific assumptions about future developments in global energy markets, and the forecasting methodologies incorporated in NEMS. Each AEO includes a "Reference" case as well as a range of alternative scenarios that each incorporate somewhat different assumptions from those underlying the Reference Case.

For the proposal, the agencies used the AEO 2017 version of NEMS, as this was the most current version of the model that was available at the time. Using this version of NEMS, the agencies reevaluated the "Reference," "Low Oil Price," and "High Oil Price" cases described in AEO 2017, by setting aside their assumption that mandates by California and other States to sell "Zero Emission Vehicles" (ZEVs) would be enforced. The agencies used the resulting modified Reference case fuel prices as inputs to the proposal's central case results, and used the modified "Low Oil Price" and "High Oil Price" case fuel prices, which were generated using NEMS, as inputs to several of the sensitivity analysis cases that were presented in the proposal. The sensitivity analysis also included a case that applied the Reference case fuel prices from the then recently issued AEO 2018, which did not reflect the modification of EIA's forecasting model to set aside state mandates for ZEV sales.[1090]

The analysis supporting the proposed rule simulated the economic impacts of car and light truck manufacturers' compliance with alternative CAFE and CO_2 standards through model year 2032, and in doing so estimated the number of vehicles originally produced and sold in each model year that would remain in service during each year of their useful lives (assumed to extend for a maximum of 40 years), as well as their usage, fuel consumption, and safety performance. This required the forecasts of macroeconomic variables that affect vehicle sales, use, and retirement rates, which include U.S. Gross Domestic Product (GDP), the size of the domestic labor force, and key interest rates, to extend well beyond calendar year 2050. One of the few sources that provides forecasts of these variables spanning such a long time horizon was the

[1090] The results of these and other sensitivity analyses were reported in NHTSA and EPA, "Notice of Proposed Rulemaking: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks," Federal Register Vol. 83, No. 165, August 24, 2018, Tables VII-90 to VII-98, pp. 43353-69.

2017 OASDI Trustees Report from the U.S. Social Security Administration, and the analysis supporting the proposed rule relied on this source for forecasts of these key macroeconomic measures.[1091]

(a) Comments on the fuel price forecasts and macroeconomic assumptions used in the NPRM analysis

The agencies received relatively few comments on the forecasts of fuel prices and macroeconomic variables that were used in their analysis supporting the proposed rule, virtually all of them focused on the fuel price forecasts the agencies employed. While only one comment questioned the agencies' use of price forecasts that rely on EIA's methodology and assumptions, a few commenters called attention to the unreliability of price forecasts reported in earlier editions of AEO. Other comments noted the importance of updating forecasts used to analyze the proposal to reflect more recent developments in energy markets, without necessarily questioning the reliability of EIA's fuel price projections. Several comments emphasized the implications for the agencies' analysis of the wide variation in alternative fuel price forecasts reported in both EIA's 2017 and 2018 Annual Energy Outlooks, with most stressing the possibility that future prices might be above even those projected in their High Oil Price cases. Only a single comment identified a potential alternative source of fuel price forecasts, but noted that it was within the range of forecasts the agencies considered.

One commenter claimed that AEO's projections of fuel prices are "inappropriate" for the agencies to employ in analyzing the consequences of CAFE and CO_2 standards; because EIA "does not speculate on changes in international policy or geopolitics," which contribute to the uncertainty surrounding future prices.[1092] However, this commenter did not identify an alternative source for fuel price forecasts that reflect such considerations; and, because forecasts of fuel prices are a central element in the agencies' evaluation of alternative future standards, the observation that EIA's forecasts do not incorporate some sources of uncertainty is unhelpful by itself.

Some commenters asserted that, by relying on the AEO 2017 Reference Case forecasts of fuel prices in their central analysis of the proposed rule while considering the significantly higher fuel prices forecast in the AEO High Oil Price scenario only in the accompanying sensitivity analyses, the agencies inadequately considered the possible effect of higher fuel prices on the estimated economic benefits from alternatives that would have relaxed the augural standards, including the preferred alternative.[1093] However, supplemental material included in the NPRM

[1091] Social Security Administration, *The 2017 Annual Report of the Board of Trustees of the Federal Old-Age and Survivors Insurance and Federal Disability Insurance Trust Funds*, available at https://www.ssa.gov/OACT/TR/2017/.

[1092] NHTSA-2018-0067-11837, Alliance to Save Energy, p. 2 ("EIA takes a transparently conservative approach in modeling future oil prices, and does not speculate on changes in international policy or geopolitics. As a result, their projections are an inappropriate measure of future fuel prices.").

[1093] *See e.g.*, Securing America's Future Energy (SAFE), NHTSA-2018-0067-11981, pp. 12 & 30 and Institute for Policy Integrity, NHTSA-2018-0067-12213, p. 31.

regulatory docket showed that the ranking of regulatory alternatives by their estimated net economic benefits remained unchanged from the central analysis in the sensitivity analysis that substituted the AEO 2017 High Oil Price case forecast of fuel prices. None of these commenters observed that the agencies' analogous use of lower fuel price forecasts from the AEO 2017 Low Oil Price scenario only in their sensitivity analyses inadequately considered the possibility that future fuel prices might prove to be *lower* than projected in the AEO 2017 Reference Case, and its potential effect on the proposal's estimated benefits. Nor did any of the commenters offer substantive guidance about how the agencies might revise their analysis to accord greater emphasis to fuel price forecasts above (or below) those from the AEO Reference Case.[1094] Somewhat surprisingly, none of these comments acknowledged that the fuel price forecasts reported in the High Oil Price scenarios accompanying past editions of the Annual Energy Outlook have so far proven to be significantly above actual prices, or that EIA has consistently lowered its fuel price forecasts in more recent editions of AEO.

Other comments stressed the fact that EIA's current forecasts of future fuel prices are significantly lower than those the agencies relied on when they established CAFE standards through model year 2021 and introduced the augural standards for subsequent model years in the rulemaking they conducted in 2012, citing this as support for the agencies' reconsideration of the augural standards in the current rulemaking.[1095]

One comment compared the range of fuel price forecasts spanned by the High and Low Oil Price scenarios from AEO 2017 and AEO 2018 to the range of future prices spanned by another widely-recognized and relied-upon forecast, concluding that the alternative scenarios included in AEO 2017 incorporated an even wider range of uncertainty about future prices, and noted that the net economic benefits of the preferred alternative were positive over this entire range of alternative future fuel prices. This same commenter noted that by combining high and low fuel price forecasts with alternative assumptions about other key economic variables (such as GDP growth) and parameter assumptions (principally payback period), the agencies' sensitivity analyses captured potentially important interactions between uncertainty regarding fuel prices and other key economic inputs.[1096]

[1094] One commenter did refer to guidance to EPA contained in a National Research Council report on incorporating and conveying uncertainty about key inputs directly into that agency's estimates of benefits from reducing air pollution, rather than simply recognizing it in supplemental sensitivity analyses. This was presumably intended as potential guidance to the agencies about how they might do so in their evaluations of fuel economy and CO_2 standards, although that was not stated explicitly. *See* American Fuel & Petrochemical Manufacturers, NHTSA-2018-0067-12078, p. 19, citing National Research Council (2002), *Estimating the Public Health Benefits of Proposed Air Pollution Regulations*, 2002, available at https://www.nap.edu/catalog/10511/estimating-the-public-health-benefits-of-proposed-air-pollution-regulations.

[1095] For example, Fiat Chrysler Automobiles (FCA) pointed out that the AEO 2017 Reference Case forecast of gasoline prices through 2025 is approximately 36% lower than that in the AEO 2012 Reference Case, which the agencies relied on in the analysis supporting that earlier rulemaking; see NHTSA-2018-0067-11943, p. 33.

[1096] *See* Alliance of Automobile Manufacturers, NHTSA-2018-0067-1207, p. 108.

(b) Macroeconomic assumptions used to analyze economic consequences of the final rule

After considering these comments, the agencies have concluded there is no convincing reason to rely on sources other than EIA's NEMS model to project future energy prices, or to rely on alternatives to the Reference Case scenario in the current edition of AEO as their basis for using NEMS. The agencies agree that the resulting projections will be uncertain, but note that EIA regularly publishes retrospective analyses comparing past Reference case projections to subsequent market price outcomes, thus enabling an assessment of this uncertainty. Although EIA does not identify its Reference case as a "most likely" outcome, in the agencies' judgment that case's design—which assumes future trends are consistent with historical and current market behavior—makes it a reasonable and appropriate basis for projecting fuel prices to use in the agencies' central analysis of alternative CAFE and CO_2 standards.

The agencies also conclude that the wide range of uncertainty about future petroleum prices encompassed in EIA's "Low Oil Price" and "High Oil Price" means that including them in the accompanying sensitivity analyses provides a meaningful basis for assessing the potential economic consequences of future energy prices that prove to be considerably lower or higher than those reflected in the Reference case. Although these alternative cases do not incorporate unbridled speculation regarding hypothetical changes in "international policy or geopolitics," the agencies believe that this restraint means that relying on them produces a more, rather than less, meaningful test of the effect of the inherent uncertainty surrounding forecasts of fuel prices.

For today's final rule, the agencies have therefore used the AEO 2019 version of NEMS to develop forecasts of future prices for transportation fuels, as this was the most current version available when this analysis was conducted. Using this version of NEMS, the agencies modified EIA's AEO 2019 reference case by (1) setting aside presumed enforcement by California and other States of any mandates to sell "Zero Emission Vehicles" (ZEVs), (2) setting aside post-2020 increases in the stringency of CAFE and CO_2 standards, and (3) modifying inputs regarding battery costs, in order to bring those costs down to levels more consistent with battery cost estimates applied in the CAFE model analysis.[1097] All other NEMS inputs used to develop the AEO 2019 Reference case were left unchanged in this analysis.

Commented [A268]: REVISE: This seems wrong: the baseline is the augural standards, and the policy case is 1.5% increasing year over year.

Setting aside enforcement of state mandates to sell ZEVs makes the supporting analysis consistent with the agencies' recent One National Program Action,[1098] under which EPA withdrew aspects of a Clean Air Act Preemption waiver previously granted to California and NHTSA concluded that EPCA expressly and implied preempted State ZEV mandates. Setting aside the post-2020 increase in the stringency of CAFE and CO_2 standards ensures that the fuel prices used in the agencies' analysis are at least as high as those that would prevail under the least stringent regulatory alternative considered, since that alternative produces the highest level of fuel consumption and thus the highest fuel prices.

Commented [A269]: REVISE: Why is that a good reason?

[1097] These inputs are all contained in the "trnldvx.xlsx" NEMS input file. The version of NEMS utilized for today's analysis is available [add reference], as is the corresponding output file from which reference case fuel and electricity prices were obtained to be used as inputs to the CAFE model.
[1098] 84 FR 51310.

Figure I-31Figure I-31 and Figure I-32Figure I-32 below show the resulting modified forecasts of BEV prices and sales, and compare them to the forecasts reported in EIA's AEO 2019 Reference case. As they illustrate, the combination of these modifications led NEMS to project significantly lower BEV prices and correspondingly higher BEV sales volumes. Figure I-33Figure I-33 and Figure I-34Figure I-34 show the modified forecasts of gasoline and electricity prices, and again compare these to the forecasts reported in EIA's AEO 2019 Reference case. As those figures indicate, the agencies' modifications to NEMS did not significantly affect its projections of future prices for transportation fuels.

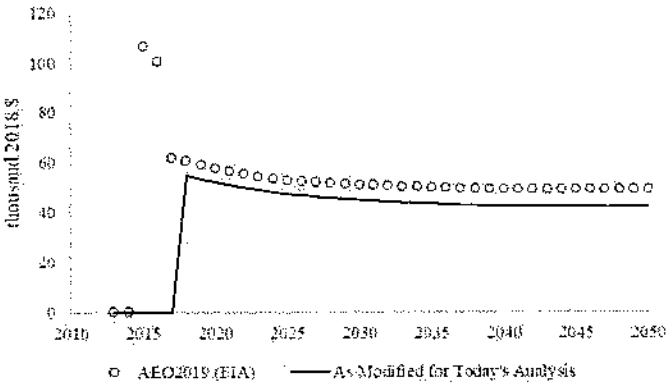

Figure I-31 - NEMS-Based BEV Prices (Showing 300-Mile Midsize Car)

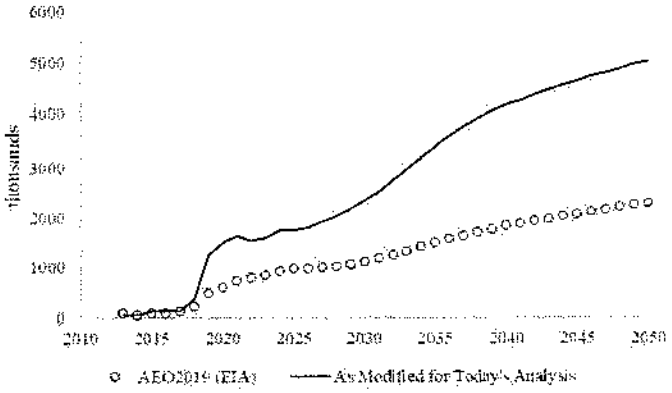

Figure I-32 - NEMS-Based BEV Sales

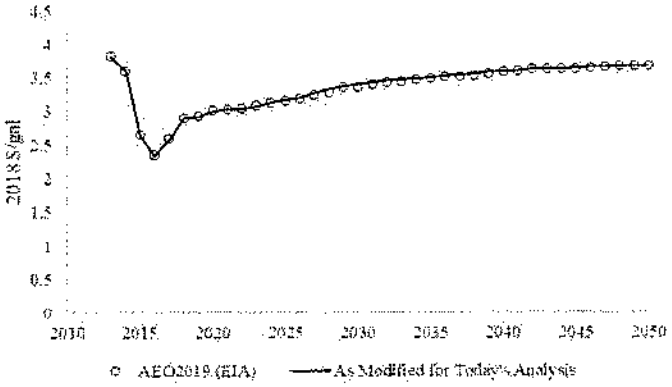

Figure I-33 - NEMS-Based Gasoline Prices

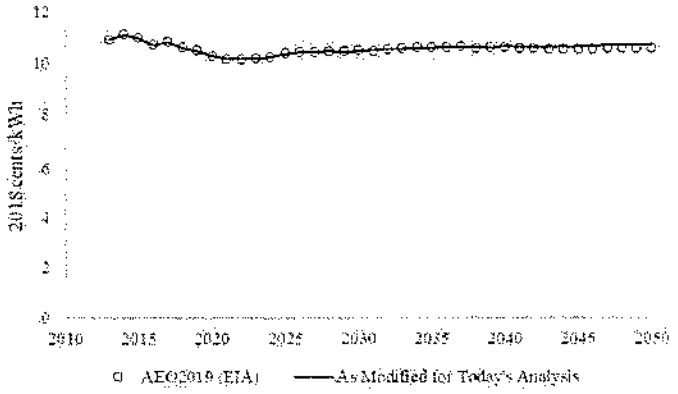

Figure I-34 - NEMS-Based Electricity Prices

The agencies used the resulting Reference case fuel prices as inputs to the rule's central analysis. The agencies also used the as-published (by EIA) "Low Oil Price" and "High Oil Price" case fuel prices as inputs to several of the cases included in the sensitivity analysis presented in the accompanying RIA. The forecast future values of fuel prices under each of these scenarios are reported in Tables [Text Forthcoming].

For the forecasts of macroeconomic variables used in the analysis supporting this rule, the agencies elected to rely on different sources from those that informed their analysis of the proposed rule. Specifically, the agencies rely on forecasts of future growth in U.S. GDP reported in AEO 2019 to support their central analyses of the final rule's impacts on new car and light truck sales and the retirement of used vehicles. These incorporate underlying forecasts generated using the IHS Markit Global Insight long-term macroeconomic forecasting model, as modified via this model's interaction with NEMS' representation of global energy markets and their future outcomes. The alternative forecasts of future growth in GDP used in the agencies' accompanying sensitivity analyses are drawn from the AEO 2019 High Economic Growth and Low Economic Growth cases. These reflect alternative future trends in U.S. labor force and productivity growth, and are also consistent with the energy market outcomes projected by NEMS under the resulting future performance of the U.S. economy.

For estimates of the number of U.S. households during future years, which influence the projections of new car and light truck sales used in the analysis, the agencies rely on projections of new household formation developed the Harvard University Joint Center for Housing

Studies.[1099] These are consistent with the most recent projections of future growth in the nation's population prepared by the U.S. Bureau of the Census.[1100]

(2) Approach to estimating sales response under different standards

Prior to the NPRM, all previous CAFE and CO_2 rulemaking analyses used static fleet forecasts that were based on a combination of manufacturer compliance data, public data sources, and proprietary forecasts (or product plans submitted by manufacturers). When simulating compliance with regulatory alternatives, those analyses projected identical sales across the alternatives, for each manufacturer down to the make/model level—where the exact same number of each model variant was assumed to be sold in a given model year under both the least stringent alternative (typically the baseline) and the most stringent alternative considered (intended to represent "maximum technology" scenarios in some cases). To the extent that an alternative matched the assumptions made in the production of the proprietary forecast, using a static fleet based upon those assumptions may have been warranted. However, a sales forecast is unlikely to be representative of a broad set of regulatory alternatives with significant variation in the cost of new vehicles. A number of commenters on previous regulatory actions encouraged consideration of the potential impact of fuel efficiency standards on new vehicle prices and sales, and the changes to compliance strategies that those shifts could necessitate.[1101] In particular, the continued growth of the utility vehicle segment creates compliance challenges within some manufacturers' fleets as sales volumes shift from one region of the footprint curve to another, or as mass is added to increase the ride height of a vehicle on a sedan platform to create a crossover utility vehicle, which exists on the same place of the footprint curve as the sedan upon which it might be based.

However, some NPRM commenters referenced the agencies' previous omission of this effect as justification to continue ignoring this issue in the current rulemaking. EDF commented,[1102] "use of a sales response model constitutes an unexplained reversal in the agency's position on the feasibility of doing so." To say that the agencies never used a model is a misrepresentation. Assuming that sales never change in any model year, even at the individual nameplate level, regardless of the stringency of fuel economy regulations or the technology costs required to comply with those regulations, is, itself, a model. It is a model that implicitly asserts that, while fuel economy regulation impacts vehicle prices, such regulations have no impact on the quantity or mix of new vehicle sold, regardless of stringency. This is an implicit argument that new vehicle demand is perfectly inelastic—and that no change in vehicle prices can impact the number of cars consumers will buy. Logically, however, there must exist a level of stringency that would have a negative impact on new sales. Picking an extreme example to prove the point, if the agencies set standards at an extraordinarily stringent level that forced all

Commented [A270]: **REVISE:** This section provides a long discussion that appears to conclude that NHTSA is unable to estimate sales response. It also says that it divides the analysis into 2 parts – an aggregate sales projection and the effects of prices on sales (p. 491), but none of that is in this section. Other than this section providing responses to comments, what is its purpose?

Peer reviewers thought that the sales model should be integrated with the scrappage model to produce more reasonable results. How is that addressed?

Commented [A271]: **REVISE:** In the 2010 FRM, sales impacts were estimated but not used in the primary analysis.

[1099] *See* Harvard University Joint Center for Housing Studies, Updated Household Growth Projections: 2018-2028 and 2028-2038, December 18, 2018, available at https://www.jchs.harvard.edu/sites/default/files/Harvard_JCHS_McCue_Household_Projections_Rev010319.pdf.
[1100] *Ibid.*, pp. 2-5.
[1101] *See, e.g.*, Comment by Alliance of Automobile Manufacturers, Docket ID EPA-HQ-OAR-2015-0827-4089 and NHTSA-2016-0068-0072.
[1102] NHTSA-2018-0067-12108-42.

vehicles into battery electric propulsion systems next year, sales would obviously be impacted. The increase in new vehicle price or changes to other relevant attributes like range, refueling time, or operating cost would surely affect the decisions of some buyers. But, by arguing that the agencies should continue to model new vehicle sales as if they are entirely unaffected by standards, commenters are effectively asking the agencies to assume that the alternatives considered in this rule are insufficiently stringent to affect the market. By endorsing the approach from the 2012 final rule, which assumed no impact on the new vehicle market from standards as stringent as 7 percent increase, year-over-year, beginning in 2017, commenters are suggesting that even *those* standards would have no impact on new vehicle sales. Manufacturers have asserted in their comments that fuel economy regulations change both the cost of producing new vehicles and consumer demand for them. In the recent peer review of the NPRM release of the CAFE model, all reviewers encouraged the inclusion of a sales response to fuel economy regulations (albeit not necessarily the version of the response model that appeared in the NPRM).[1103] Based on earlier comments and our own analysis, the agencies were persuaded to include a sales response mechanism in the NPRM, and do so again in this final rule.

Commented [A272]: **REVISE:** A few papers (Haaf et al. 2014, 2016; Doremus et al. 2018) have now argued that holding sales response constant is a better predictor than using a vehicle sales model. If that's true, what's the merit of using a model that finds changes? Gruenspecht, in his peer review of the sales model, notes that the wrong model may be worse than no sales response.

More to the point, commenters are arguing here that the uncertainty in the linkage between the standards and sales is so vast that declining to model it will result in predictions that are at least as good, if not better than, any one model.

Rephrasing the commenters' argument as "assuming that the alternatives considered in this rule are insufficiently stringent to affect the market" is rephrasing the question into a form that's easier to answer, and thereby sidestepping the original issue – a logical fallacy.

While several commenters (CARB, NCAT, CBD, Aluminum Association) discouraged the agencies from attempting to account for the effect of regulations on new vehicle sales, other commenters stated that the NPRM analysis was improved by explicitly considering this effect (RFF, Toyota, the Alliance of Automobile Manufacturers). CBD cited EPA's 2016 proposed determination, stating "[a] reasonable qualitative assessment is preferable to a quantitative estimate lacking sufficient basis, or (due to uncertainties like those here) having such an enormous range as to be without substantial value."[1104] However, RFF supported the inclusion of the effect (with caveats about the specific implementation, for which they suggested alternative approaches), stating "[i]ncorporating sales and scrappage effects represents a step in the right direction for modeling the effects of the regulation.[1105] It is reasonable to conclude that regulations as transformative as fuel economy standards will impact the market for new vehicles, and excluding the effect (as CBD and others suggested) is equivalent to stating that it does not exist.

The NPRM version of the sales response relied on differences in the average price of new vehicles to produce sales differences between regulatory alternatives. Some commenters (ACEEE, IPI, CBD, UCS, Aluminum Association, and Alliance to Save Energy) argued that new vehicle prices do not increase with the addition of technology required to comply with fuel economy regulations. Some argued that manufacturers will choose not to "pass through" the full incremental cost of fuel saving technologies to consumers, instead absorbing those costs into their profit margin.[1106, 1107] The question of cost pass-through is one that academic and industry

[1103] CAFE Model Peer Review, DOT HS 812 590, Revised (July 2019), available at https://www.regulations.gov/contentStreamer?documentId=NHTSA-2018-0067-0055&attachmentNumber=2&contentType=pdf
[1104] NHTSA-2018-0067-12000-69.
[1105] NHTSA-2018-0067-11789-14.
[1106] NHTSA-2018-0067-12213-28.
[1107] NHTSA-2018-0067-12123-26.

researchers have considered for decades—and two of our recent peer reviewers addressed this issue in their comments.

Dr. John D. Graham, one of the peer reviewers, argued that the assumption of complete cost pass-through is defensible, and more likely in the long-run than the short-run.[1108] The reviewer also suggested that changes to the CAFE (and subsequent CO_2) program that base a manufacturer's standard on the mix of vehicle footprints in each fleet more equitably spreads the impact of the standards across the industry, and that industry shifts toward increasingly competitive market models (rather than the oligopolistic models that existed earlier in the last century) both act to increase the likelihood that manufacturers will pass regulatory costs through to consumers. In particular, this reviewer stated:

> In a classic study, Gron and Swenson (2000)[1109] examined list prices of automobiles at the model level in the US from 1984 to 1994 coupled with data on production, vehicle characteristics, foreign versus domestic firm ownership, wages of employees, exchange rates, imported parts content, tariffs and other variables. Although their work rejects the hypothesis of 100% pass through of cost to consumer price, they find higher rates of pass through than previous studies, and much of the incomplete pass through occurs when cost increases impact only a few models or firms. Confirming earlier studies, they show that US auto manufacturers engage in more aggressive pass-through pricing than Asian and European manufacturers (greater than 100% in some specifications), possibly due to the eagerness of importers to enlarge market share in lieu of recovering regulatory costs, at least in the short run (see Dinopolous and Kreinin, 1988;[1110]; Froot, 1989[1111]). This study helps explain why pass-through pricing is a more viable hypothesis in the long run than in the short run.
>
> The original design of the CAFE program is a contrasting case where pass-through pricing was difficult for some automakers. All auto makers, regardless of their product mix, were subject to the same fleet-wide average CAFE standard, such as 27.5 miles per gallon for cars in 1990. In practice, those standards impacted only three high-volume companies (General Motors, Ford and Chrysler) because the Big Three produced a higher proportion of large and performance-oriented vehicles than did Japanese companies. As a result, manufacturers such as Toyota and Honda consistently surpassed the federal fleet-wide standard for cars without any regulatory cost (i.e., partly due to their smaller product mix). In the 1975-2007 period, the Big Three were not able to pass

[1108] CAFE Model Peer Review, DOT HS 812 590, Revised (July 2019), pp. B31-B33, available at https://www.regulations.gov/contentStreamer?documentId=NHTSA-2018-0067-0055&attachmentNumber=2&contentType=pdf

[1109] Gron Anne, Swenson, Deborah L., Cost Pass-Through in the US Automobile Market, Review of Economics and Statistics, Vol. 82(2) (May 2000), at 3.

[1110] Dinopoulos, Elias, Kreinin, Mordechai, Effects of U.S.-Japan Auto VER on European Prices and on US Welfare, [THIS REVIEW] Vol. 70(3) (1988), at 484-91.

[1111] Froot, Kenneth A, Klemperer, Paul D, Exchange Rate Pass-Through When Market Share Matters, American Economic Review, Vol. 79(4) (1989), at 637-54.

on all of their compliance costs to consumers and thus experienced some declines in profitability due to CAFE (Kleit, 1990[1112]; Kleit, 2004[1113]; Jacobsen, 2013[1114]).

When the CAFE program was reformed for light trucks in 2008 (and for cars in 2011) on the basis of vehicle size (the so-called "footprint" adjustments to CAFE stringency), the, the technology costs of CAFE standards were spread more evenly among automakers, although the overall societal efficiency of the regulation diminished due to the removal of downsizing as a compliance option .[1115] Given that the size-based fuel economy programs are not concentrating the costs of compliance on one or two automakers, it is reasonable to predict a fairly high degree of pass-through pricing for the 2021-2025 fuel economy standards. In related literature on manufacturer pricing responses to a national carbon tax, Bento and Jacobsen (2007)[1116] and Bento (2013)[1117] report high rates of pass-through pricing (on the order of 85%). Carbon taxes are more efficient than footprint-based CAFE standards, but both instruments are likely to impact a wide range of companies in the auto sector and result in a high degree of pass-through pricing by impacted companies.

Also, it should be noted that the US automotive industry is much more competitive today than it was from 1970 to 2000. The market share of General Motors, once the dominant, majority producer in the U.S. market, has declined dramatically, and a variety of Japanese and Korean companies have captured substantial market share. Moreover, the rise of startups (e.g., Tesla and other electric vehicle start-ups) and ride-sharing services (e.g., Uber) are adding a new competitive dimension in the U.S. industry. As a result, some of the most recent auto regulatory studies have given more emphasis to analytic results based on competitive models than oligopolistic models (see, e.g., Davis and Knittel (2016)[1118]).''

Another peer reviewer, Dr. James Sallee, suggested that costs would pass through to new vehicle buyers to different degrees, depending upon the stringency of the standards.[1119] The reviewer argued that more stringent standards, which result in larger increases to the cost of production, are likely to induce greater degrees of pass-through than less stringent standards, which automakers may, as some commenters have suggested, be able to absorb in the form of

Commented [A273]: **REVISE:** It reduced downsizing as an option, but, if some vehicle buyers prefer larger vehicles, that may be an ancillary benefit.

Commented [A274]: **REVISE:** 85% < 100%.

[1112] Kleit, Andrew N., The Effect of Annual Changes in Automobile Fuel Economy Standards, Journal of Regulatory Economics, Vol. 2, (1990.), at 151-72.
[1113] Kleit, Andrew N, Impact of Long-Range Increases in the Fuel Economy (CAFE) Standard, Economic Inquiry, Vol. 42(2) (2004), at 279-94.
[1114] Jacobsen, Mark R., Evaluating US Fuel Economy Standards in a Model with Producer and Household Heterogeneity, American Economic Journal: Economic Policy, Vol. 5(2) (2013), at 148-87.
[1115] *See* Ito, Koichiro, Sallee, James M., The Economics of Attribute-Based Regulation: Theory and Evidence from Fuel-Economy Standards, Review of Economics and Statistics, in press (2018).
[1116] Bento, Antonio M., Jacobsen, Mark R, Environmental Policy and the 'double-dividend' hypothesis, Journal of Environmental Economics and Management, Vol. 53(1) (January 2007) at 17-31.
[1117] Bento, Antonio M. Equity Impacts of Environmental Policy, Annual Review of Resource Economics, Vol. 5 (May 2013), at 181-96.
[1118] Davis, Lucas, Knittel, Christopher R., Are Fuel Economy Standards Regressive? Working Paper 22925, National Bureau of Economic Research, Cambridge, MA (2016).
[1119] [Cite Sallee review.]

lost profit. If the degree of cost pass-through should vary by the stringency of the alternative, we are underestimating the difference in price between the most and least stringent alternatives—which would favor alternatives with higher stringency.

Other commenters argued that manufacturers are able to compensate fully for the costs of fuel economy standards by increasing the prices of luxury vehicles—which would increase the average new vehicle price, but leave large sections of the market unaffected by the increased cost of producing fleets that comply with the standards. While it seems likely that manufacturers employ pricing strategies that push regulatory costs (as well as increases in costs like pension obligations and health care costs for employees) into the prices of models and segments with less elastic demand, the extent to which any OEM is able to succeed at this is unknown by the agencies. At some point, however, price increases on even luxury models will merely price more and more purchasers out of the market, and make competition with other manufacturers and market segments that much more difficult. And the more that avoided price increases for lower ends of the vehicle market are subsidized by luxury vehicles, the more either prices for luxury models would need to be increased, or (if moderately increasing prices) more of those luxury models would need to be sold. It is worth noting that luxury vehicles tend to be more powerful and content-rich, and often have fuel economy levels below (or CO_2 levels above) their targets on the curves—so that selling more of them to compensate for lost profit elsewhere further reduces the ability to comply with standards.

Commented [A275]: **REVISE:** This discussion is very narrowly focused on the effects of price increases. The standards will also affect fuel economy and thus operating costs. Are those irrelevant here?

Also, what does the evidence indicate? The fact that average vehicle prices have risen isn't a good indicator, because it doesn't account for changes in sales mix. How have prices changed for, e.g., specific classes?

While manufacturers could conceivably push some small cost increases into the prices of their vehicle segments that have less elastic demand to cover accordingly small increases in stringency, larger stringency increases would exhaust the ability of such segments to absorb additional costs. In addition, we do not attempt to adjust the mix of vehicle models based on their own price elasticity of demand; doing so would require a pricing model that takes the compliance cost for each manufacturer (which our model estimates dynamically) and apportions that cost to the prices of individual nameplates and trim levels. We have experimented with pricing models (when integrating vehicle choice models, pricing models are a necessity), but each manufacturer almost certainly has a unique pricing strategy that is unknown to the agencies, and involves both strategic decisions about competitive position within a segment and the volumes needed fully to amortize fixed costs associated with production. [To the extent that the agencies assume all regulatory costs are passed through and affect the average regulatory cost of each vehicle instead of being priced in a fashion to minimize the impact on aggregate sales, the agencies note that—more stringent alternatives are provided an artificial analytical advantage because manufacturers are better positioned to incorporate smaller price fluctuations into their business plan. The agencies opted to take the conservative approach instead of speculating on manufacturer's private business models.]

Commented [A276]: **REVISE OR DELETE:** What is the chain of logic here? In the case of any standards, manufacturers may have some market power to reduce the effects of the standards on themselves. It's not obvious how looser or tighter standards will affect that ability. Nor is it obvious how that affects consumer markets.

Finally, some commenters have argued that, even if regulations *do* increase the cost of producing vehicles and those costs *are* passed on to new vehicle buyers, it does not matter because sales have increased in recent years under both rising standards and rising prices. EDF, CARB, Aluminum Association, SAFE, CBD, and CA et al. and Oakland et al., all make some

version of this argument in their comments.[1120,1121,1122,1123,1124,1125] The commenters are confusing correlation with causation and failing to consider the counterfactual case. Higher prices of new vehicles certainly did not cause sales to increase since 2012. Sales increased over that period, in large part, as a result of economic expansion following the great recession.[1126] The statistical model used in the NPRM attempted to isolate the effect of average price on new vehicle sales, independent of the overall health of the US economy which plays an obviously important role. That model showed a negative relationship between sales and price (albeit a modest one), and positive relationships with GDP and employment. Even under the most stringent alternative in the NPRM, sales increased over time. However, in other alternatives, where the same macroeconomic conditions prevailed but average new vehicle prices were lower, sales increased relative to the baseline. That is the counterfactual case that is relevant for regulatory analysis—it attempts to answer the question, "would sales have been even higher if average prices had been lower?"

Commented [A277]: REVISE: That model was not well reviewed. It might be better to rely on academic literature on the subject rather than a not-well-supported model.

As we discuss below, identifying the independent contribution of price to new vehicle sales is econometrically challenging. In the NPRM, we stated that the simultaneous nature of price and sales—where transaction prices are higher in periods of higher demand, because the market will bear them, and lower in periods of lower demand, because the market will not, for an otherwise identical vehicle—creates a form of reverse causality. As commenters suggested, in recent years sales have increased along with average transaction price increases—and transaction price increases will occur when regulation forces manufacturers to add content, and their corresponding costs, to the vehicles they sell. Thus, it is understandable that some commenters could interpret the recent increase in new vehicle sales following the recession as evidence that standards (and maybe prices) have no impact on new sales. However, that view confuses correlation for causation (or lack thereof, in this case). This misunderstanding is related to some of the specific econometric comments about the NPRM model.

In response to these comments, the agencies have modified their approach to modeling the impacts of sales. In order to isolate the impact of the standards, the agencies have broken the sales response module into two discrete components. The first captures the effects of broader economic forces such as GDP. The second measures how vehicle prices influence sales. As elaborated in more detail in the following passages, the agencies considered alternative and specific changes suggested by commenters, but concluded that the comments either lacked enough information to implement a change, failed to remedy identified alleged weaknesses of the model, or created new limitations for which there were no practical solutions. Furthermore, the two-pronged approach addresses many of the concerns raised by commenters better than any specific modeling alteration. First, the structural changes to the model address many of the econometric concerns raised by commenters. Second, by modeling sales in the first step as a function of macroeconomic conditions, and then applying an independent own-price elasticity to

[1120] NHTSA-2018-0067-12108-76.
[1121] NHTSA-2018-0067-11873-116.
[1122] NHTSA-2018-0067-11952-4.
[1123] NHTSA-2018-0067-11981-17.
[1124] NHTSA-2018-0067-12123-26.
[1125] NHTSA-2018-0067-11735-69.
[1126] Table VI-88Table VI-88 below shows a large and statistically significant effect of GDP on sales.

estimate the change in sales across alternatives, we are able to more clearly distinguish between demand-side and supply-side impacts on prices, the issue that appears to have tripped up some of the commenters.

Comments on the econometric model used in the NPRM

Any model of sales response must satisfy two requirements: it must be appropriate for use in the CAFE model, and it must be based in both sound economic theory and appropriate empirical analysis ~~econometrically reasonable~~. The first of these requirements implies that forecasts of any variable used in the estimation of the econometric model must also be available as a forecast throughout the duration of the years covered by the simulations (this analysis explicitly simulates compliance through MY 2050). Some values the model calculates endogenously, making them available in future years for sales estimation, but others must be known in advance of the simulation. As the CAFE model simulates compliance, it accumulates technology costs across the industry and over time. By starting with the last known average transaction price (associated with MY 2016, in this analysis) and adding accumulated regulatory costs to that value, the model is able to represent an estimated average selling price in each future model year, assuming that manufacturers are able to pass their compliance costs on to buyers of new vehicles. Other variables used in the estimation can be entered into the model as inputs prior to the start of the compliance simulation.

Commented [A278]: CHANGE AS SHOWN: Soundly based in both economic theory and empirical data. And, it should reasonably consider other research on the subject.

The NPRM analysis was based on an econometric model that attempted to estimate the price elasticity of aggregate demand for new light-duty vehicles based on exogenous factors, intended to represent (1) macroeconomic forces that influence demand for new vehicles, and (2) average new vehicle price, intended to represent the impact of regulation. A number of commenters voiced opposition to the approach. Some disagreed with the theoretical framing of the issue—arguing that the model of sales response should have acknowledged the relevance of other vehicle attributes, included consumer valuation of fuel savings for new vehicles, based the response on something other than price, and considered the effect at a lower level of aggregation, rather than average price across the industry.

In the NPRM, the agencies relied upon an autoregressive distributed lag (ARDL) statistical model to estimate the impact of price differences between regulatory alternatives and to produce a time series of total new vehicle sales in each year of the analysis. The statistical model estimated new vehicle sales per year based on two lagged variables of new sales (new sales in the previous period, and the period before that), GDP and lagged GDP, and labor force participation and lagged labor force participation. The model used quarterly data and seasonally adjusted annual rates to increase the number of observations over the sample period for which reliable sales data existed (1978-2015). The ARDL model used in the NPRM was chosen to address sales impacts at a high level of aggregation, namely the total new vehicle market (across all vehicle brands and body styles), and to resolve the econometric issues associated with the time series data related to total new vehicle sales.

Stock et al. commented at length on the econometric specification of the NPRM sales response model, identifying limitations and suggesting alternative approaches.[1127] In particular, they argued that the length of the response to price shocks should dissipate faster than the NPRM model allows—an artifact of using quarterly data and seasonally adjusted annual rates to estimate the effect and implementing it on an annual basis in the CAFE model. We agree that this was a flaw in the implementation of the NPRM model. While this approach produced the correct units (i.e., annual sales) the response to changes in price should have dissipated at a quarterly rate, rather than an annual rate. As a result, a single price shock, which appears in one year and disappears the next, was projected to have a longer impact on sales in future years than was appropriate given the specification. The sales response in the final rule corrects for this objective error and takes a more conservative approach to price shocks.

Stock et al. commented that "it is important to estimate the dynamic effect on sales of a price increase, that is, the causal effect on current and future demand of a price increase" because "it allows the response to an intervention—here, a one-time price increase or sequence of such increases—to evolve over time."[1128] The comment suggests that we should include future responses in sales to a one-time price increase that exists for a single period and then disappears. In our analytical framework, this implies that a price difference between any alternative and the baseline that causes a difference in sales in that year should also produce a difference in sales in the following year (and possibly subsequent years), though of smaller magnitude, even if the price difference only exists for a single period. The Stock et al. comment illustrates a quickly diminishing response to a single price shock. The final rule assumes (more conservatively) that each price shock lasts only for a single year, and produces no future "ripple" effects in the new vehicle market in subsequent years. Furthermore, the regulatory alternatives considered in this analysis do not produce single period price shocks (in the form of price differences between alternatives), but rather persistent price differences between alternatives that result from continued differences in stringency. The persistent nature of the price differences resulting from fuel economy and CO_2 regulations further reduce the importance of capturing these multi-period effects caused by single-period price shocks.

Stock et al. also objected to the use of an ARDL model to estimate the impact of price on new vehicle sales. In order for the estimation of causality to be valid in a time series model, the current price movements must be uncorrelated with unobserved demand shocks in the past, present, and future; so-called strict exogeneity. The commenters argue that the NPRM fails this test because actions taken in the market (by both buyers and sellers) can influence the response to price changes in the next period. They suggest the use of a vector autoregression (VAR) model to address the relationship between past demand disturbances and current prices to address the temporal exogeneity issues they identify. However, an important caveat is that this approach still does not resolve the largest econometric challenge—that of contemporaneous endogeneity between price and sales (in the same period). To address that challenge, one needs to employ instrumental variable methods.

[1127] EPA–HQ–OAR–2018–0283 and NHTSA–2018–0067
[1128] Ibid.

We attempted several modifications to the statistical model developed for the NPRM based on the Stock et al. comment. We reviewed the initial approach and attempted several specifications that would explicitly address the temporal endogeneity bias identified in the comment. In particular, we addressed data limitations that were raised by Stock et al. (and also by EDF), who encouraged us to reconsider the quarterly specification and to use quality-adjusted price data for new vehicles in order to ensure a more consistent definition of the average vehicle over the time series. The quarterly price series was statistically interpolated in the NPRM to increase the number of observations,[1129] but represented a less-than-ideal solution. The interpolating process may have impacted the underlying quarterly data generating process, resulting in unreliable, or potentially biased, regression results. This issue was remedied by sourcing both vehicle sales and price data from IHS Markit, which provides these data at the same base frequency (quarterly). In addition, the macroeconomic data used in the model specification were also sourced from IHS, which provides consistency between historical and forecast data (i.e., forecasts of sales, price, personal income, etc., were all based on a consistent set of input assumptions and modeling framework during testing).

Historical quarterly series for new light vehicle average price and total sales are presented in Figure VI-35Figure VI-35 below. Due to the lack of data availability for business investment in light vehicles, the historical series for average vehicle price begins in 1987. Average prices were transformed into quality adjusted real terms using the CPI for new motor vehicles, and both series were seasonally adjusted.[1130] Quality adjusted prices have risen overtime, while total sales have remained relatively flat in recent years with the major exception being the significant economic downturn of 2008-2009. The difference in these trends suggests that the number of vehicles purchased per household does not necessarily change, or grow, over time, as income grows, but rather households adjust the "amount" of new vehicle they are willing to purchase (i.e., switching from sedan to an SUV).[1131] Moreover, while disposable income has steadily increased during this period, sales have not seen the same type of upward trend, and instead only returned to its pre-recession average of around 17 million annual sales.

Commented [A279]: **REVISE:** Sales have increased steadily after the recession, and exceeded pre-recession levels, as clearly shown in the graph.

[1129] Interpolation is the practice of adding unobserved data points based on observed trends to provide more observations to a limited data set.
[1130] Seasonal adjustment was made using X.12 in EViews.
[1131] Aggregate light duty vehicle sales data does not allow for observing the distribution of vehicles being sold, which will have an effect on the average price.

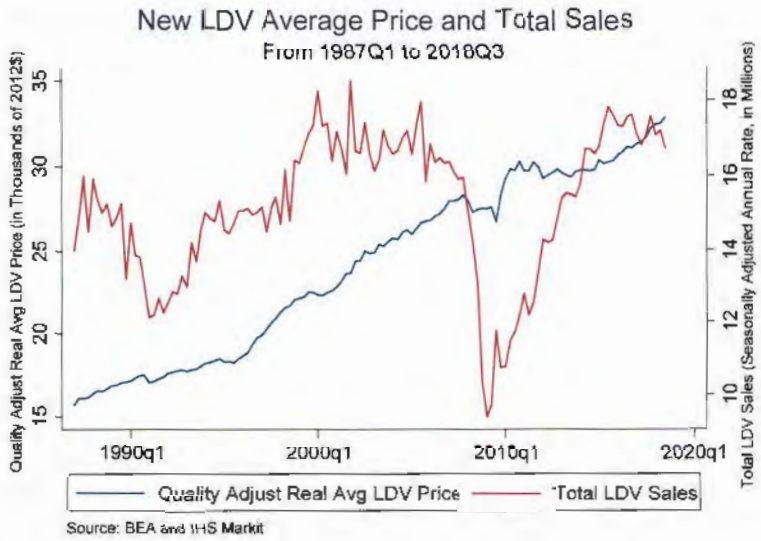

Figure VI-35 - New Light Duty Vehicle Average Price and Total Sales

Even as real disposable income has risen since 2000, and outside of the great recession, new vehicle sales have remained relatively steady. This, in turn, suggests there are other economic, or behavioral, factors beyond disposable income influencing the decision to purchase a new vehicle. Given the significant cost to purchase a new vehicle, and the long multiyear timeframe over which they are typically financed, households' forward-looking view on the health of the economy likely plays a role in their willingness to purchase a new vehicle. Put differently, households may delay their purchasing decisions if their view outlook on the economy sours, regardless of income level. These observations are consistent with the framework of the NPRM model, and Figure VI-36Figure VI-36 presents the consumer sentiment index and total new sales, with both series exhibiting similar trends over this period. Some commenters advocated that consumer sentiment (also known as consumer confidence) should be included in the sales forecast. For example, the Aluminum Association indicated that prior sales models have shown consumer behavior to be "highly sensitive to macroeconomic conditions, consumer confidence and employment levels." While consumer sentiment was not included in the NPRM model, it was included in specifications that we tested and considered and is a component of the forecasting model used in the final rule.[1132]

[1132] Commenters mentioned consumer confidence as a predictor of consumer behavior. For instance, the Aluminum Association indicated that prior sales models have shown consumer behavior to be "highly sensitive to macroeconomic conditions, consumer confidence and employment levels."

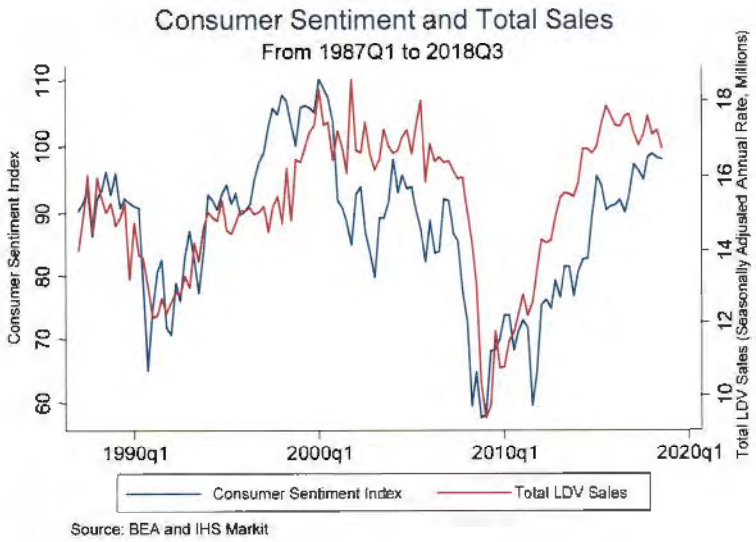

Figure VI-36 - Consumer Sentiment and Total Sales

All macroeconomic data were sourced from IHS including real disposable income, number of US households, and the University of Michigan's consumer sentiment index. The summary statistics for all series are presented below in Table VI-88Table VI-88.

Table VI-88 - Summary Statistics

Variable	Obs.	Mean	Std.	Min	Max
Quality Adjusted Real Avg. LDV Price (Thousands, 2012$)	127	24.13	5.29	15.74	32.89
Total LDV Sales (SA Annual Rate, Millions)	127	15.23	1.93	9.38	18.53
Real Disposable Income (Billions, 2012$)	127	9,979.94	2,432.22	6,113.99	14,358.03
Number of Households (Millions)	127	110.36	9.19	93.53	126.35

Consumer Sentiment Index	127	87.66	11.68	57.67	110.13

Each series was transformed into natural logarithms and tested for stationarity using the modified Dicky-Fuller test.[1133] Results presented in Table VI-89Table VI-89 indicate each variable containing contained a unit-root, while being differenced stationary (i.e. integrated of order one).

Table VI-89 - Modified Dickey-Fuller Test (1 lag)

	DF-GLS Test Stat.	1% Critical Value	5% Critical Value	10% Critical Value
NL Quality Adjusted Real Avg. LDV Price	-1.224	-3.548	-2.995	-2.704
Δ NL Quality Adjusted Real Avg. LDV Price	-5.803	-3.549	-2.996	-2.706
NL Total LDV Sales	-1.841	-3.548	-2.995	-2.704
Δ NL Total LDV Sales	-6.352	-3.549	-2.996	-2.706
NL Total LDV Sales per Household	-1.855	-3.548	-2.995	-2.704
Δ NL Total LDV Sales per Household	-6.375	-3.549	-2.996	-2.706
NL Real Disposable Income	-0.855	-3.548	-2.995	-2.704
Δ NL Real Disposable Income	-4.593	-3.549	-2.996	-2.706
NL Real Disposable Income per Household	-1.091	-3.548	-2.995	-2.704

[1133] Using nonstationary variables would generate unreliable estimates, as prior values of those variables are correlated their future values, and this violates the assumption that values variables take on are independent over time.

Δ NL Real Disposable Income per Household	-4.589	-3.549	-2.996	-2.706
NL Consumer Sentiment Index	-2.332	-3.548	-2.995	-2.704
Δ NL Consumer Sentiment Index	-8.991	-3.549	-2.996	-2.706

Two separate variables lists were then tested for the existence of one or more cointegrating relationships, with results from the Johansen test presented in Table VI-90Table VI-90.[1134] In each set of variables, both total LDV sales and disposable income were converted to household units as a means to control for the growth in US households and the possible decision making process of buying/consuming a new unit of LDV. The results show that 4 out of the 5 lag length selections for both variable sets conclude there being one cointegrating relationship (rank I(1)) among them.

Table VI-90 - Johansen Test for Cointegration

Series	Lags	Max Rank	Trace Stat.	5% Critical Value
NL LDV Sales per HH, NL PDI per HH, NL Avg. LDV Price	2	1	9.9139	15.41
	3	0	28.6582	29.68
	4	1	8.8639	15.41
	5	1	7.9938	15.41
	6	1	12.6687	15.41
NL LDV Sales per HH, NL PDI per HH, NL Avg. LDV Price, NL JCSM	2	2	10.2220	15.41
	3	1	25.8108	29.68
	4	1	29.2521	29.68

[1134] The number of lag lengths were also tested formally, with general consensus between 2 and 6 lags as being optimal. Test results are available upon request, however, the final lag length selection was determined on the full set of VAR and VECM output that includes satisfying time series conditions such as no presence of autocorrelation and plausible interpretability of the estimated output.

5	1	21.7739	29.68
6	1	27.1268	29.68

Note: NHH, PDI, and JCSM refer to households, real personal disposable income, and consumer sentiment, respectively. All tests include an unrestricted constant. Alternative tests were conducted to include restricted trend or constant terms, but are not presented here for brevity as our preferred specification only includes an unrestricted constant term in the model.

Taken together, these tests confirm the need to address the time series properties of each variable in any modeling framework. This will become especially important when discussing the correct modeling approach, as The pre-modeling tests provide evidence against running a simple OLS regression or VAR in first differences, because doing so would have the potential outcome of excluding important long-run information.

Furthermore, the endogeneity between vehicle sales and price is another element that needs to be considered for model specification. The IHS historical series for average price of a new light duty vehicle is defined as a function of business and private residential spending on light vehicles divided by total new light vehicle sales; from this identity, the average price represents the nominal price per new unit of light duty vehicle sold. This definition supports the existence of an endogenous relationship between vehicle price and sales that needs to be accounted for when developing an econometric estimation of the influence of new vehicle price on sales. This is consistent with economic theory, whereby vehicle sales and price are simultaneously determined in the market, and therefore should be included together when specifying a forecasting equation.[1135] This restriction holds even if nominal vehicle price is transformed into a quality adjusted real dollar series, as some commenters (EDF, Stock et al) proposed.[1136]

Models

Faced with the simultaneity problem associated with price and sales, several specifications were reviewed to determine the best method for addressing this issue. An Instrumental Variable (IV) method was deemed the most direct approach, with the advantage of preserving the initial model's autoregressive distributed lag structure. In order to obtain consistent estimates of the price elasticity of demand, a suitable instrument that is correlated with average LDV price but uncorrelated with the error term is needed in the first stage. A suitable instrument must also make economic sense and have a plausible causal relationship. In theory, instruments that satisfy all three conditions (exogeneity, causality, and non-weak correlation) should exist. In practice, however, it is often prohibitively difficult to find a viable instrument. Both Stock et al. and CARB suggested instrumenting to resolve the endogeneity issue in the NPRM model, but neither suggested specific candidates for instrumental variables.

[1135] Endogeneity results in correlation between an independent variable in a regression and the error term leading to biased coefficient estimates.

[1136] For reference on how the BLS measures quality adjustments in vehicles: https://www.bls.gov/cpi/factsheets/new-vehicles.htm.

For the purposes of modeling vehicle sales, candidate IVs would reflect the price of inputs to production that are broad enough, so that the underlying behavior of the variable is not deterministic of LDV sales. Examples of candidate variables include producer price indices (PPIs) of auto or other related manufacturing, cost of capital required for production, labor market data, energy costs, technology changes, and exogenous shocks to price, production, labor, or policy changes.

The lack of data availability and quality concerns reduced the primary list of candidate IVs to relatable PPIs such as for manufacturing and automobile primary products. Even the most "promising" candidate IVs, however, proved to be poor instruments, with counterintuitive signs, lack of statistical significance, and poor overall first stage F-statistics (even by relatively lenient weak instrument test standards).

The lack of reasonable results from the IV approach led to testing vector autoregressive (VAR) and vector error correction (VECM) models. Relaxing the strict exogeneity assumption needed under an ARDL framework is the main advantage of modeling price, sales, and macroeconomic variables as a system of equations where the feedback from previous period shocks affect both price and sales.[1137] In addition, a VAR or VECM can also adequately handle the time series and nonstationary properties discussed above. For both the VAR and VECM, a parsimonious specification was preferred with either a three or four variable system using the variables discussed above.

We first estimated a simple VAR using a Wold causal ordering of real disposable income per household, average price of new LDV, and new total sales of LDVs per household.[1138] The alternative specification included the consumer sentiment variable in the ordering the consumer sentiment variable after income and before price. This ordering assumes that households' disposable income (and consumer sentiment) do not respond to shocks to auto prices and sales within the same quarter. It also assumes that prices are contemporaneously exogenous of sales (demand), since the MSRPs are set in advance. Lastly, sales are able to respond to unexpected changes in price in the same quarter. The alternative ordering of placing sales before average price was deemed unrealistic as it would presume sales responding independently to an unexpected change in prices.

In the first specification, all variables were transformed to first differences to ensure stationarity, while ignoring any possible long-run information (for the moment). A combination of post-estimation tests for autocorrelation and stability conditions were considered along with impulse response functions to gauge the model performance. The preferred model was estimated with five lags, and the impulse response functions (IRF) of a 1 percent shock to price on sales for the two specifications are presented in Figure VI-37.

[1137] Strict exogeneity requires there to be past, contemporaneous, and future exogeneity between the variables of interest.

[1138] The Wold causal ordering creates a lower triangular matrix for our shocks, so by construction these shocks are orthogonal to each other to allow for causal inference. This recursive or Wold ordering technique should be predetermined and based on economic theory as the causal interpretation of the impulse responses are dependent on the correct/plausible ordering of variables.

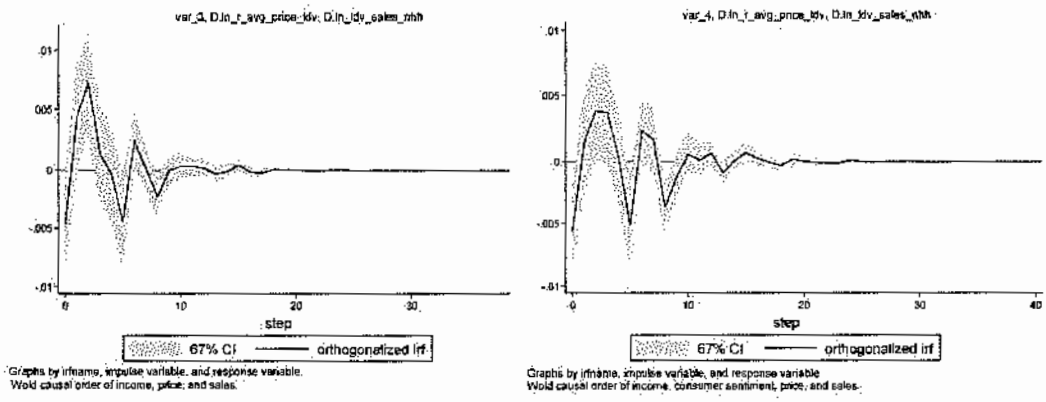

Figure VI-37 - Impulse Response Functions of Price on Sales from First Difference VARs

Both figures show a similar trend of the response in sales oscillating from negative to positive before ultimately returning to zero 12 quarters out. The three variable VAR sees a positive response in the first few periods, while the four variable VAR manages to dip below zero briefly after 4 periods out. This behavior, which by definition is short-run due to the differencing of the variables, could be representing auto dealerships' attempts to pull sales back to its equilibrium level after the price shock pushes sales negative, implying some level of over compensation during this process. Nonetheless, despite the model showing there is some evidence of an immediate and negative price elasticity, the overly simplified VAR model is missing key long run information (as identified in the cointegration tests), creating some reservations about the results. It is also worth noting that the lagged positive response in sales from an unexpected price shock is persistent regardless of the lag length selection, and in many cases even more pronounced.

A number of preliminary conclusions can be drawn from the IRF results shown in Figure VI-37. First, at least at this level of aggregation, any short-run and immediate effect of a price increase on total LDV sales is relatively small in nature. This does not suggest, however, that the price elasticity of demand is zero. Instead, what may be the case is that when faced with an unexpected change in price, consumers will choose to purchase a less expensive car with fewer options as opposed to no car at all. In other words, the level of aggregation being used, total car sales, removes important variation between the type of vehicle being sold and consumer purchasing decisions from the data; what is left is a clouded version of the true relationship between price and sales. Second, this type of VAR ignores and throws out any long run information that may exist, which would create omitted variable bias if such a cointegrated relationship exists.

Based on the conclusions from the Johansen cointegration test, the next step involved estimating the system as a VECM. As with the VAR models, the VECM employs either a three or four variable system with five lag lengths and an unconstrained constant in the model (no trend in either the first differenced or cointegrating equations). In each model, the cointegrating vector is normalized around sales (i.e. the sales' coefficient is set to 1), and the model results indicate strong evidence of a cointegrating relationship between the variables.

Aside from general agreement on a cointegrating relationship, the VECM performance was weak in nearly every specification attempted, with implausible magnitudes for the long-run coefficient estimates and insignificant short-run dynamics. Moreover, the adjustment coefficient for the sales equation is particularly weak and insignificant.[1139] The limitations of the VECM could be rooted in the system being normalized around sales, which lacks significant variation, correlation, or possibly true causation with the other variables.

As with the VAR analysis, a similar focus is placed on the IRFs presented in Figure VI-38. Here a one percent shock in price on LDV sales shows a similar response between the two specifications, with an increase during the first several periods before returning to a negative and permanent long-run effect. This response is erroneous in two ways: first, the sharp positive response during the first 8 to 10 quarters defies economic logic as an increase in the price of a normal good should not induce an increase in sales. Second, the permanent and negative effect is equally as confounding because it rules out the ability for dealerships or auto manufacturers to adjust prices or supply.[1140]

The updated econometric models of light duty vehicle sales thus did not provide clear, significant or robust insight into the magnitude of the price elasticity of demand. While the VAR model specification points to an immediate short-run negative price elasticity of demand (i.e., sales fall in the face of an immediate price shock), this relationship is relatively small. In addition, the fact that this specification excludes the identified cointegration between the variables suggests that it is not robust or unbiased. In short, the VECM and IV approaches were unable to provide reasonable and meaningful results.

These results strongly suggest that the relationship between sales and price is not adequately estimated with the macro-level data used in this analysis. Recent peer reviewers of the CAFE model had similar concerns. In particular, these data are insufficient to explain the individual consumer (micro-) level decision making process of purchasing a new LDV. Aggregating the sales response to the national level reduces the useful variation in the decision making process to levels unsuitable for estimation. Commenters generally agreed with this conclusion.

[1139] The lack of a statistically significant adjustment variable could be an indication of weak exogeneity. In this case that would not be plausible given the clear endogeneity between price and sales, and is more likely an indication of poor data and the absence of reliable modelling approaches.

[1140] Note that error bounds cannot be generated for VECM IRFs using most statistical packages, so determining statistical significance is difficult. Given the change from positive to negative and the low magnitude of the response, it is quite possible that this effect is indistinguishable from zero.

Even assuming a theoretically and econometrically correct model was possible, this relationship is impossible to evaluate at the current data aggregation level. Future research may focus on constructing an aggregate price elasticity of demand from consumer level data utilizing discrete choice modeling or something similar. However, constructing such models and integrating them into the simulations of the final rule are beyond the scope of this analysis.

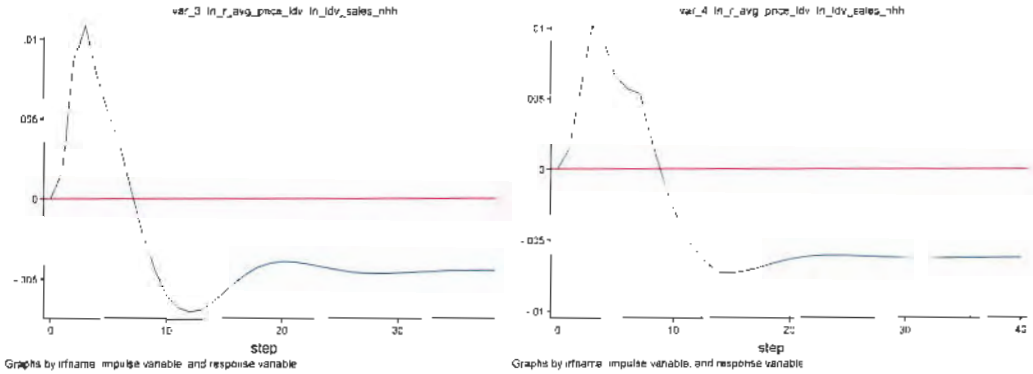

Figure VI-38 - Impulse Response Functions of Price on Sales from VECMs

Many commenters suggested that the NPRM model was unable to find a statistically significant influence of fuel economy on sales because the model was too highly aggregated, as we found with the econometric experimentation to estimate a price response. EDF, CARB, and CA et al. and Oakland et al. expressed concern that using industry averages eliminated the variation needed to detect consumer valuation of fuel economy in new vehicle purchases. We noted a similar concern in the NPRM, citing the level of aggregation as the most likely reason that the average fuel economy of a new vehicle was not a statistically significant explanatory variable in the ARDL model. The approach for the final rule includes an average value of improved fuel economy in the sales response, as commenters suggested it should.

Commented [A280]: REVISE: EPA agrees that consumer valuation of fuel economy is important for estimating the effect of the standards on vehicle sales.

EPA disagrees that consumer valuation of fuel economy is the only concern in the energy paradox. The Draft TAR demonstrated that the MY 2012-16 standards saved consumers more than the technology costs, without observed adverse effects on other vehicle attributes, without observed lack of options for consumers, and without apparent consumer opposition or blowback. Thus, the paradox exists. Why it exists may not be well understood. Putting all the explanatory power on consumer valuation, however, does not explain the facts. As noted below, if consumers fully value fuel economy (and automakers respond in measure), then the standards couldn't have done what they did – have fuel savings > tech costs. If consumers undervalue fuel economy, then there should have been consumer resistance to the vehicles. Neither of those logical outcomes of focusing entirely on consumers has been true. So putting all the responsiblity for the energy paradox on consumer valuation doesn't explain what has occurred since the standards went into effect.

a. How do Car and Light Truck Buyers Value Improved Fuel Economy?

Many commenters (CARB, CA et al and Oakland et al., NRDC, EDF, CBD, North Carolina Department of Environmental Quality, IPI, Stock et al.) stated that the agencies should explicitly consider fuel savings, and the value that consumers ascribe to it, in addition to changes in price when estimating the response of new vehicle sales to different regulatory alternatives. NRDC stated,[1141] "The decision between new vehicle purchase alternatives must consider both

[1141] NHTSA-2018-0067-11723-26.

differential costs and differential benefits. The CAFE model sales algorithm considers only differential costs and is, therefore, flawed." The agencies agree that the degree to which new vehicle buyers value improvements in fuel economy is an important consideration when estimating the response of new vehicle sales to potential standards. The effect of vehicle prices on sales is difficult to detect at the aggregate level because price movements are correlated with the current strength of the economy, which can appear as a positive price elasticity when modeling sales, and there are various technical econometric difficulties in identifying the effect of price on sales (simultaneity, cointegration, etc., addressed above). The sales response model in the final rule accounts for fuel savings realized by buyers of new vehicles.

Some commenters noted that the sales response equation omitted any value of fuel savings to new vehicle buyers, while other elements of the analysis—notably the technology application algorithm—assumed that buyers would demand fuel economy technologies that "pay back" within the first 2.5 years of ownership (as a result of avoided fuel costs), and manufacturers would supply fuel economy at those levels even in the absence of standards. This observation was made in comments by CARB, CBD, and IPI—the last of which stated that2.5 year payback assumption "clashes directly with the contradictory assumption that the agencies rely on in the model's sales module, where they implicitly assume that customers entirely disregard fuel efficiency in their purchasing decisions."[1142] We agree that this represented an internal inconsistency. The sales model used to analyze the final rule includes the estimated value of fuel savings to vehicle buyers, and is consistent with other assumptions throughout the analysis about the "pay back" period.

How potential buyers value improvements in the fuel economy of new cars and light trucks is an important issue in assessing the benefits and costs of government regulation. If buyers fully value the savings in fuel costs that result from higher fuel economy, manufacturers will presumably will supply any improvements that buyers demand, and vehicle prices will fully reflect future fuel cost savings consumers would realize from owning—and potentially re-selling—more fuel-efficient models. If consumers internalize fuel savings this case, more stringent fuel economy standards will impose net costs on vehicle owners and can only result in social benefits through correcting externalities, since because consumers would already fully incorporate private savings into their purchase decisions, as discussed further in Section [Market Failure]. If instead consumers systematically undervalue some market failure such as an information asymmetry leads to an underinvestment in fuel-saving technology, the cost savings generated by improvements in fuel economy when choosing among competing models, more stringent fuel economy standards will also lead manufacturers to adopt improvements in fuel economy that buyers might not choose despite the cost savings they offer and improve consumer welfare.

Commented [A281]: **REVISE:** Sales is the way that consumer WTP affects the rule's net benefits. The bulk of this paragraph is theory, not based on measured impacts. As noted above, the theory doesn't match actual experience with increasingly stringent standards.

The potential for car buyers voluntarily to forego improvements in fuel economy that offer savings exceeding their initial costs is one example of what is often termed the "energy-efficiency gap." This appearance of such a gap, between the level of energy efficiency that would minimize consumers' overall expenses and what they actually purchase, is typically based

[1142] NHTSA-2018-0067-12213-15.

on engineering calculations that compare the initial cost for providing higher energy efficiency to the discounted present value of the resulting savings in future energy costs.

Commented [A282]: **REVISE:** Incorrect. The gap is about technologies & costs, not consumer behavior. What's observed is that, after the standards went into effect, there was rapid uptake of previously-existing technologies with net negative costs and no apparent adverse effects on other vehicle characteristics. That's the gap.

There has long been an active debate about why such a gap might arise and whether it actually exists. Economic theory predicts that individuals will purchase more energy-efficient products only if the savings in future energy costs they offer promise to offset their higher initial costs. However, the additional up-front cost of a more energy-efficient product includes more than just the cost of the technology necessary to improve its efficiency; because consumers have a scarcity of resources, it also includes the opportunity cost of any other desirable features that consumers give up when they choose the more efficient alternative. In the context of vehicles, whether the expected fuel savings outweigh the opportunity cost of purchasing a model offering higher fuel economy will depend, among other things, on how much its buyer expects to drive, his or her expectations about future fuel prices, the discount rate he or she uses to value future expenses, the expected effect on resale value, and whether more efficient models offer equivalent attributes such as performance, carrying capacity, reliability, quality, or other characteristics.

Published literature has offered little consensus about consumers' willingness-to-pay for greater fuel economy, and whether it implies over-, under- or full-valuation of the expected discounted fuel savings from purchasing a model with higher fuel economy. Most studies have relied on car buyers' purchasing behavior to estimate their willingness-to-pay for future fuel savings; a typical approach has been to use "discrete choice" models that relate individual buyers' choices among competing vehicles to their purchase prices, fuel economy, and other attributes (such as performance, carrying capacity, and reliability), and to infer buyers' valuation of higher fuel economy from the relative importance of purchase prices and fuel economy.[1143] Empirical estimates using this approach span a wide range, extending from substantial undervaluation of fuel savings to significant overvaluation, thus making it difficult to draw solid conclusions about the influence of fuel economy on vehicle buyers' choices.[1144] Because a vehicle's price is often correlated with its other attributes (both measured and unobserved), analysts have often used instrumental variables or other approaches to address endogeneity and other resulting concerns.[1145]

Commented [A283]: REVISE: Add Greene et al. "Consumer Willingness to Pay for Vehicle Attributes: What Do We Know?" Transportation Research Part A 118 (2018): 258-279.

Despite these efforts, more recent research has criticized these cross-sectional studies; some have questioned the effectiveness of the instruments they use ,[1146] while others have observed that coefficients estimated using non-linear statistical methods can be sensitive to the optimization algorithm and starting values.[1147] Collinearity (i.e., high correlations) among vehicle attributes—most notably among fuel economy, performance or power, and vehicle size—and between vehicles' measured and unobserved features also raises questions about the reliability and interpretation of coefficients that may conflate the value of fuel economy with

[1143] In a typical vehicle choice model, the ratio of estimated coefficients on fuel economy—or more commonly, fuel cost per mile driven—and purchase price is used to infer the dollar value buyers attach to slightly higher fuel economy.
[1144] *See* Helfand & Wolverton (2011) and Green (2010) for detailed reviews of these cross-sectional studies.
[1145] *See, e.g.*, Barry, et al. (1995).
[1146] *See* Allcott & Greenstone (2012).
[1147] *See* Knittel & Metaxoglou (2014).

other attributes (Sallee, et al., 2016; Busse, et al., 2013; Allcott & Wozny, 2014; Allcott & Greenstone, 2012; Helfand & Wolverton, 2011).

In an effort to overcome shortcomings of past analyses, three recently published studies published fairly recently rely on panel data from sales of individual vehicle models to improve their reliability in identifying the association between vehicles' prices and their fuel economy (Sallee, et al. 2016; Allcott & Wozny, 2014; Busse, et al., 2013). Although they differ in certain details, each of these analyses relates changes over time in individual models' selling prices to fluctuations in fuel prices, differences in their fuel economy, and increases in their age and accumulated use, which affects their expected remaining life, and thus their market value. Because a vehicle's future fuel costs are a function of both its fuel economy and expected gasoline prices, changes in fuel prices have different effects on the market values of vehicles with different fuel economy; comparing these effects over time and among vehicle models reveals the fraction of changes in fuel costs that is reflected in changes in their selling prices (Allcott & Wozny, 2014). Using very large samples of sales enables these studies to define vehicle models at an extremely disaggregated level, which enables their authors and to isolate differences in their fuel economy from the many other attributes, including those that are difficult to observe or measure, that affect their sale prices.[1148]

Commented [A284]: REVISE: Even more recent: Leard et al., "How Much Do Consumers Value Fuel Economy and Performance? Evidence from Technology Adoption," RFF Report, https://media.rff.org/documents/RFF-Rpt-WTP_FuelEconomy26Performance.pdf ; Gillingham et al., "Consumer Myopia in Vehicle Purchases: Evidence from a Natural Experiment." https://environment.yale.edu/gillingham/GillinghamHoudevanBenthem_ConsumerMyopia.pdf

These studies point to a somewhat narrower range of estimates than suggested by previous cross-sectional studies; more importantly, they consistently suggest that buyers value a large proportion—and perhaps even all—of the future savings that models with higher fuel economy offer.[1149] Because they rely on estimates of fuel costs over vehicles' expected remaining lifetimes, these studies' estimates of how buyers value fuel economy are sensitive to the strategies they use to isolate differences among individual models' fuel economy, as well as to their assumptions about buyers' discount rates and gasoline price expectations, among others. Since Anderson et al. (2013) found evidence that consumers expect future gasoline prices to resemble current prices, we use this assumption to compare the findings of the three studies and examine how their findings vary with the discount rates buyers apply to future fuel savings.[1150]

[1148] These studies rely on individual vehicle transaction data from dealer sales and wholesale auctions, which includes actual sale prices and allows their authors to define vehicle models at a highly disaggregated level. For instance, Allcott & Wozny (2014) differentiate vehicles by manufacturer, model or nameplate, trim level, body type, fuel economy, engine displacement, number of cylinders, and "generation" (a group of successive model years during which a model's design remains largely unchanged). All three studies include transactions only through mid-2008 to limit the effect of the recession on vehicle prices. To ensure that the vehicle choice set consists of true substitutes, Allcott & Wozny (2014) define the choice set as all gasoline-fueled light-duty cars, trucks, SUVs, and minivans that are less than 25 years old (i.e., they exclude vehicles where the substitution elasticity is expected to be small). Sallee et al. (2016) exclude diesels, hybrids, and used vehicles with less than 10,000 or more than 100,000 miles.

[1149] Killian & Sims (2006) and Sawhill (2008) rely on similar longitudinal approaches to examine consumer valuation of fuel economy except that they use average values or list prices instead of actual transaction prices. Since these studies remain unpublished, their empirical results are subject to change, and they are excluded from this discussion.

[1150] Each of the studies makes slightly different assumptions about appropriate discount rates. Sallee et al. (2016) use five percent in their base specification, while Allcott & Wozny (2014) rely on six percent. As some authors note, a five to six percent discount rate is consistent with current interest rates on car loans, but they also

As Table VI-88Table VI-88Table 1 indicates, Allcott & Wozny (2014) found that consumers incorporate 55% percent of future fuel costs into vehicle purchase decisions at a six percent discount rate, when their expectations for future gasoline prices are assumed to reflect prevailing prices at the time of their purchases. With the same expectation about future fuel prices, the authors report that consumers would fully value fuel costs only if they apply discount rates of 24 percent% or higher. However, these authors' estimates are closer to full valuation when using gasoline price forecasts that mirror oil futures markets, because the petroleum market expected prices to fall during this period (this outlook reduces the discounted value of a vehicle's expected remaining lifetime fuel costs). With this expectation, Allcott & Wozny (2014) find that buyers value 76% percent of future cost savings (discounted at six percent) from choosing a model that offers higher fuel economy, and that a discount rate of 15 percent% would imply that they fully value future cost savings. Sallee et al. (2016) begin with the perspective that buyers fully internalize future fuel costs into vehicles' purchase prices and cannot reliably reject that hypothesis; their base specification suggests that changes in vehicle prices incorporate slightly more than 100 percent% of changes in future fuel costs. For discount rates of five to six percent, the Busse et al. (2013) results imply that vehicle prices reflect 60 to 100 percent% of future fuel costs. As Table VI-91Table VI-91 suggests, higher private discount rates move all of the estimates closer to full valuation or to over-valuation, while lower discount rates imply less complete valuation in all three studies.

acknowledge that borrowing rates could be higher in some cases, which could be used to justify higher discount rates. Rather than assuming a specific discount rate, Busse et al. (2013) directly estimate implicit discount rates at which future fuel costs would be fully internalized; they find discount rates of six to 21 percent% for used cars and one to 13 percent% for new cars at assumed demand elasticities ranging from -2 to -3. Their estimates can be translated into the percent of fuel costs internalized by consumers, assuming a particular discount rate. To make these results more directly comparable to the other two studies, we assume a range of discount rates and uses the authors' spreadsheet tool to translate their results into the percent of fuel costs internalized into the purchase price at each rate. Because Busse et al. (2013) estimate the effects of future fuel costs on vehicle prices separately by fuel economy quartile, these results depend on which quartiles of the fuel economy distribution are compared; our summary shows results using the full range of quartile comparisons.

Table VI-91 - Percent of Future Fuels Costs Internalized in Used Vehicle Purchase Price using Current Gasoline Prices to Reflect Expectations (for Base Case Assumptions)

Authors (Pub. Date)	**Discount rate**			
	3%	**5%**	**6%**	**10%**
Busse, et al. (2013)*	54%-87%	60%-96%	62%-100%	73%-117%
Allcott & Wozny (2014)	48%		55%	65%
Sallee, et al. (2016)		101%		142%

*Note: The ranges in the Busse et al. estimates depend on which quartiles of the fuel economy distribution are compared. With no prior on which quartile comparison to use, this analysis presents the full quartile comparison range.

The studies also explore the sensitivity of the results to other parameters that could influence their results. Busse et al. (2013) and Allcott & Wozny (2014) find that relying on data that suggest lower annual vehicle use or survival probabilities, which imply that vehicles will not last as long, moves their estimates closer to full valuation, an unsurprising result because both reduce the changes in expected future fuel costs caused by fuel price fluctuations. Allcott & Wozny's (2014) base results rely on an instrumental variables estimator that groups miles-per-gallon (MPG) into two quantiles to mitigate potential attenuation bias due to measurement error in fuel economy, but they find that greater disaggregation of the MPG groups implies greater undervaluation (for example, it reduces the 55 percent% estimated reported in Table VI-88Table VI-88Table 1 to 49 percent%). Busse et al. (2013) allow gasoline prices to vary across local markets in their main specification; using national average gasoline prices, an approach more directly comparable to the other studies, results in estimates that are closer to or above full valuation. Sallee et al. (2016) find modest undervaluation by vehicle fleet operators or manufacturers making large-scale purchases, compared to retail dealer sales (i.e., 70 to 86 percent%).

Since they rely predominantly on changes in vehicles' prices between repeat sales, most of the valuation estimates reported in these studies apply most directly to buyers of used vehicles. Only Busse et al. (2013) examine new vehicle sales; they find that consumers value between 75 to 133 percent% of future fuel costs for new vehicles, a higher range than they estimate for used vehicles. Allcott & Wozny (2014) examine how their estimates vary by vehicle age and find that fluctuations in purchase prices of younger vehicles imply that buyers whose fuel price expectations mirror the petroleum futures market value a higher fraction of

future fuel costs: 93 percent% for one- to three-year-old vehicles, compared to their estimate of 76 percent% for all used vehicles assuming the same price expectation.[1151]

Accounting for differences in their data and estimation procedures, the three studies described here suggest that car buyers who use discount rates of five to six percent value at least half—and perhaps all—of the savings in future fuel costs they expect from choosing models that offer higher fuel economy. Perhaps more important in assessing the case for regulating fuel economy, one study suggests that buyers of *new* cars and light trucks value three-quarters or more of the savings in future fuel costs they anticipate from purchasing higher-mpg models, although this result is based on more limited information.[1152]

In contrast, previous regulatory analyses of fuel economy standards implicitly assumed that buyers undervalue even more of the benefits they would experience from purchasing models with higher fuel economy, so that, without increases in fuel economy standards, little improvement would occur, and the entire value of fuel savings from raising CAFE standards represented private benefits to car and light truck buyers themselves. For instance, in the EPA analysis of the 2017-2025 model year CO_2 standards, fuel savings alone added up to $475 billion (at three percent discount rate) over the lifetime of the vehicles, far outweighing the compliance costs: $150 billion). The assertion that buyers were unwilling to take voluntary advantage of this opportunity implies that collectively, they must have valued less than a third ($150 billion/$475 billion = 32 percent%) of the fuel savings that would have resulted from those standards. In fact, those earlier analyses assumed that new car and light truck buyers attach relatively little value to higher fuel economy, since their baseline scenarios assumed that fuel economy levels would not increase in the absence of progressively tighter standards, despite increasing fuel prices. The evidence reviewed here makes that perspective extremely difficult to justify and would call into question any analysis that claims to show large private net benefits for vehicle buyers attributable to increases in fuel economy standards.

Commented [A285]: REVISE: Incorrect. The previous analysis was based on engineering analysis and historic observations, not assumptions about consumer behavior.

Commented [A286]: REVISE: The opportunity was frequently not available to them. E.g., in MY 2010, the full range of fuel economy for minivans was 18-20 mpg. If you wanted a more efficient minivan, where was the choice?

What analysts assume about consumers' vehicle purchasing behavior, particularly about potential buyers' perspectives on the value of increased fuel economy, clearly matters a great deal in the context of benefit-cost analysis for fuel economy regulation. In light of this recent evidence on this question, warrants a more nuanced approach that is more nuanced than merely assuming that buyers drastically undervalue benefits from higher fuel economy, (and that, as a consequence, these benefits are unlikely to be realized without stringent fuel economy standards) seems warranted. One possible approach would be to use a baseline scenario where fuel economy levels of new cars and light trucks reflected full (or nearly so) valuation of fuel savings by potential buyers in order to reveal whether setting fuel economy standards above market-determined levels could produce net social benefits. Another might be to assume that, unlike in the agencies' previous analyses, where buyers were assumed to greatly to undervalue higher fuel economy under the baseline but to value it fully under the proposed standards, buyers value

[1151] Allcott & Wozny (2014) and Sallee, et al. (2016) also find that future fuel costs for older vehicles are substantially undervalued (26-30%).% percent).%). The pattern of Allcott and Wozny's results for different vehicle ages is similar when they use retail transaction prices (adjusted for customer cash rebates and trade-in values) instead of wholesale auction prices, although the degree of valuation falls substantially in all age cohorts with the smaller, retail price based sample.

[1152] [Text Forthcoming]

improved fuel economy identically under both the baseline scenario and with stricter CAFE standards in place.

The agencies requested comment on the consumer valuation of fuel economy and its use in the NPRM analysis. CBD and the North Carolina Department of Environmental Quality took issue with the agencies' characterization of the literature on the value of fuel economy, citing EPA's previous determination that the estimates in the literature represented too large a range, and the degree of uncertainty made including a value of fuel economy challenging. This final rule analysis accounts for the value of fuel economy in several places, though it uses a more conservative value than is suggested by the literature summarized above. Manufacturers have consistently told the agencies that new vehicle buyers will pay for about 2 or 3 years' worth of fuel savings before the price increase associated with providing those improvements begins to impact affect sales. We have assumed the same valuation, 2.5 years, in all components of the analysis that reflect consumer decisions regarding vehicle purchases and retirements.[1153]... This analysis explicitly assumes that: 1) consumers are willing to pay for fuel economy improvements that pay back within the first 2.5 years of vehicle ownership (at average usage rates); 2) manufacturers know this and will provide these improvements even in the absence of regulatory pressure; 3) potential buyers weigh these savings against increases in new vehicle prices when deciding to retire a vehicle; and 4) the amount of technology for which buyers will pay rises (or falls) with rising (or falling) fuel prices.[1154]. Excluding the value of fuel economy entirely from these calculations does not remove it from the analysis: it merely imposes an implausibly low value on the desired payback period of new vehicle buyers and manufacturers regardless of fuel prices or technology costs. And while the agencies acknowledge the uncertainty around the estimates in the literature, zero is far removed from the lower bounds of any study.

CARB asserted[1155, 1156] that the various market failures ~~alleged~~ suggested by the agencies in past rules (lack of information about fuel savings from higher MPG, inability to calculate cost savings from higher MPG, loss aversion, first-mover disadvantage), together with advertising that only emphasizes fuel economy during periods of high fuel prices, leads buyers to undervalue fuel economy. In contrast, CARB (and others—such as SCAQMD,[1157], Alliance to Save

Commented [A287]: CHANGE AS SHOWN: Unnecessarily derogatory

[1153] When accounting for social benefits and costs associated with an alternative, the full lifetime value of fuel savings is included.

[1154] NADA, the Alliance of Automobile Manufacturers, and American Fuel and Petrochemical Manufacturers argued that CAFE/ CO_2 standards have already reached the point where the price increases necessary to recoup manufacturers' increased costs for providing further increases in fuel economy outweigh the value of fuel savings, and requiring further increases in fuel economy will reduce new vehicle sales. The sales response in the final rule recognizes and incorporates the effect of fuel prices and fuel economy on new vehicle purchases. (NHTSA-2018-0067-12064-25, NHTSA-2018-0067-12073-2, NHTSA-2018-0067-12078-29)

[1155] NHTSA-2018-0067-11873-117

[1156] NHTSA-2018-0067-11873-21

[1157] NHTSA-2018-0067-11813-42

Energy,[1158], Save EPA,[1159] AAA,[1160] CBD,[1161] CFA,[1162] Consumers Union,[1163] EDF,[1164] and IPI[1165]) argues elsewhere that new vehicle buyers *do* value fuel economy highly, and nearly fully once fuel prices return to "normal" levels. The agencies' payback period assumption, and the matching adjustment it makes to changes in new car prices to account for accompanying changes in fuel economy, recognizes that on average potential car buyers value a significant share of lifetime cost savings resulting from higher fuel economy. The agencies considered longer payback periods along the lines suggested by Consumer Federation of America (CFA),[1166] but chose 2.5 years as a conservative approach. The agencies conducted a sensitivity analysis using a 5 year valuation – —the value preferred by CFA. Our assumption is consistent with survey evidence cited by the commenters, but at odds with their assertions that this program is necessary to save buyers from their own limited ability to make decisions in their best interest.

Both CAFE standards and regulation of vehicles' CO_2 emissions have increasingly been justified— in recent rulemakings—including by NHTSA and EPA—by the assertion that buyers do not take full advantage of opportunities to improve their *own* well-being, by purchasing models whose higher fuel economy will more than repay their higher initial purchase prices in the form of future savings in fuel costs. This is fundamentally different from asserting that some externality—whereby buyers' choices cause economic harm to *others*—or other market failure exists to justify regulating fuel economy or CO_2 emissions, whether at all or more aggressively than at present. ~~EPA and NHTSA have previously labeled this behavior an example of the "energy paradox," whereby consumers appear voluntarily to forego investments in energy conservation even when those initial investments appear to repay themselves – in the form of savings in energy costs – over the relatively near term.[1167] The studies summarized in this section call into question the importance or even existence of such a paradox.~~

Commented [A288]: REVISE: This is not true. EPA's analysis has been based on the engineering finding that many technologies had rapid payback periods but were not in widespread use. EPA has not come to firm conclusions on why this happened, but it seems indisputable that it was true.

The analysis presented here does not address the engineering evidence.

Commented [A289]: DELETE: Incorrect characterization of EPA's discussions of this issue. EPA's assessment of the paradox is based on the engineering evidence, not consumer or producer behavior.

IPI commented that the agencies' obligation to consider market failures in setting standards derives not just from Executive Order 12,866 but also from the agencies' respective statutes, and argued that the agencies had defined market failures too narrowly in their

[1158] NHTSA-2018-0067-11837-5
[1159] NHTSA-2018-0067-11930-11.
[1160] NHTSA-2018-0067-11979-1.
[1161] NHTSA-2018-0067-12000-32.
[1162] NHTSA-2018-0067-12005-50.
[1163] NHTSA-2018-0067-12068-31.
[1164] NHTSA-2018-0067-12108-28.
[1165] NHTSA-2018-0067-12213-34.
[1166] NHTSA-2018-0067-12005-55.
~~[1167] See, e.g., EPA Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, at https://nepis.epa.gov/Exe/ZyNET.exe/P100EZ11.TXT?ZyActionD=ZyDocument&Client=EPA&Index=2011+Thru+2015&Dbs=&Query=&Time=&EndTime=&SearchMethod=1&TocRestrict=n&Toc=&TocEntry=&QField=&QFieldYear=&QFieldMonth=&QFieldDay=&IntQFieldOp=0&ExtQFieldOp=0&XmlQuery=&File=D%3A%5Czyfiles%5CIndex%20Data%5C11thru15%5CTxt%5C00000005%5CP100EZ11.txt&User=ANONYMOUS&Password=anonymous&SortMethod=h%7C-&MaximumDocuments=1&FuzzyDegree=0&ImageQuality=r75g8/r75g8/x150y150g16/i425&Display=hpfr&DefSeekPage=x&SearchBack=ZyActionL&Back=ZyActionS&BackDesc=Results%20page&MaximumPages=1&ZyEntry=1&SeekPage=x&ZyPURL~~

proposal.[1168] Specifically, IPI stated that NHTSA's task under EPCA is "not so restricted to only protecting consumers from gas price spikes," and argued that NHTSA must also consider "externalities relating to energy security, national security, positional goods, global climate change, and air and water pollution associated with fuel production and consumption; asymmetric information, attention costs, and other information failures; internalities, including myopia; and various supply-side market failures, including first-mover disadvantage."[1169]

For EPA's task under the CAA, IPI stated that, although while EPA must "protect the planet from unchecked climate change, [it] must not ignore other related market failures that cause harm to public health and welfare, including the issnes and market failures [described for NHTSA above]."[1170] IPI argued that the proposal was arbitrary and capricious for not "consider[ing] important aspects of the problem set before the agencies by Congress," and also for not considering the market failures discussed in the 2012 final rule.[1171] CBD, *et al.*, asserted similarly that the agencies' respective statutes require their actions to be more technology-forcing than what markets would otherwise achieve, in effect arguing that innovations in technology confer external benefits that vehicle manufacturers or buyers do not fully consider.[1172]

With regard to the specific market failures CAFE and CO_2 standards could potentially address, Global Automakers suggested that climate effects are indeed an externality that more stringent standards can address,[1173] while CFA stated that regulating fuel economy and CO_2 emissions can address an extensive catalog of market failures, including externalities, marketing, availability of fuel-efficient models, transaction cost friction, information asymmetry, behavioral issues, and access to capital, among others.[1174] CFA asserted that advances in economic theory had heavily criticized the neoclassical model, and that "a great deal of empirical research supports [that] standards are seen as an important and, in many ways, preferred policy approach."[1175] On this basis, CFA stated that attribute-based standards that "are set at a moderately aggressive level" and are "consistent with the rate of improvement that the auto industry achieved in the first decade of the fuel economy standard setting program," among other things, would address the market failure.[1176]

IPI argued that regulation of fuel economy (presumably also CO_2 emissions) is necessary because "many vehicle attributes, like horsepower and size, are positional goods—that is, they confer status on buyers of cars and light truck models that feature them prominently, so regulation of fuel economy can help correct the positional externality."[1177] IPI also noted the

[1168] IPI, Appendix, NHTSA-2018-0067-12213, at 9-10.
[1169] *Id.*
[1170] *Id.*
[1171] *Id.*
[1172] Joint Summary Comments of Environmental, Advocacy, and Science Organizations [hereafter, "CBD, *et al.*"], NHTSA-2018-0067-12057, at 2, 9.
[1173] Global, Attachment A, at A-22.
[1174] CFA, main comments, NHTSA-2018-0067-12005, at 61-64.
[1175] *Id.*, at 63.
[1176] *Id.*, at 64.
[1177] IPI, Appendix, at 33.

externality of health effects associated with refueling. IPI cited Alcott and Sunstein (2015) to argue, like CFA, that fuel economy standards can correct market failures like informational failure, myopia, supply-side failures, positional externalities, etc., and by doing so, can provide net private welfare gains—that is, improve the utility of vehicle buyers *themselves*, not just that of *other* households or businesses.[1178]

EDF and CARB both asserted that an energy paradox exists in the case of fuel economy, with EDF arguing (like CFA) that information asymmetry—that is, unequal access of vehicle manufacturers and potential buyers to information about the cost savings likely to result from owning higher-mpg models—coupled with limited availability of fuel-efficient models, leads consumers to purchase vehicles with lower fuel economy than they otherwise would.[1179] CARB simply stated that the NPRM analysis did not account for the energy paradox.[1180]

The agencies agree with commenters that market failures CAFE and CO_2 standards can help to address are likely to exist, but question whether all of the phenomena in the broad catalog identified by commenters actually represent market failures, or instead simply reflect consumers' preferences for features other than fuel economy.[1181] Further, the agencies also question the extent to which more stringent CAFE and CO_2 standards are necessary to address the phenomena identified by commenters or are likely to be effective in doing so, regardless of whether they are market failures. In the agencies' view, neither the logical arguments nor the limited empirical evidence that commenters present convincingly demonstrate the capacity of more stringent CAFE and CO_2 standards to resolve, or even mitigate, any of the various phenomena commenters describe as market failures. However, this question is more appropriately addressed in Section [legal justification], as it pertains to the level of stringency chosen.

Commented [A290]: **REVISE**: As previously noted, the "market failure" is that the market did not adopt a number of fuel-saving technologies with short payback periods in the absence of the standards, while it did adopt them without notable problems once the standards were adopted. That's documented in the TAR. It may still not be resolved why this occurred, but it did.

For example, the idea that regulating fuel economy and CO_2 emissions can mitigate the consequences of inadequate access to information, simply by placing decisions that depend on complete information in regulators' hands, rather than buyers' hands, has superficial appeal. Yet commenters do not establish either that such a drastic step is necessary to overcome the inadequacy of information, or that it will be more effective than less intrusive approaches such as expanding the range of information available to buyers. As OMB Circular A-4 notes, "Because information, like other goods, is costly to produce and disseminate, your evaluation will need to do more than demonstrate the possible existence of incomplete or asymmetric information."[1182]

[1178] *Id.*, at 34. Note, however, that the reference cited does *not* address the question of whether fuel economy standards can be effective in correcting those market failures. I; instead, it explores the circumstances under which fuel economy standards can improve welfare when vehicle buyers undervalue savings in fuel costs from purchasing more fuel-efficient models. See Allcott, Hunt, and Cass R. Sunstein, "Regulating Internalities," Working Paper 20087, National Bureau of Economic Research, May 2015, available at https://www.nber.org/papers/w21187.pdf.
[1179] EDF, main comments, NHTSA-2018-0067-12018, at 88-89.
[1180] CARB, Detailed Comments, NHTSA-2018-0067-11873, at 188-189.

[1182] Circular A-4, at 5.

In the few cases where commenters cite empirical evidence to support their arguments that stricter fuel economy and CO_2 regulations are an appropriate response to market failures, if the evidence has been is limited and unpersuasive. As an illustration, the frequent assertion that buyers' widespread aversion to the prospect of financial losses makes them hesitant to purchase higher-mpg models appears to be traceable to evidence derived from classroom experiments on limited numbers of university students, rather than to empirical evidence drawn from buyers' observed behavior.[1183] Commenters' repeated emphasis on loss aversion as a critical source of buyers' unwillingness to choose levels of fuel economy that are in their own financial interest also ignores research that appears to discredit the concept as a motivation for such systematic or universal behavior by consumers.[1184]

Another example is commenters' repeated citation of the study of households' difficulties in analyzing the financial value of purchasing vehicles with higher fuel economy conducted by

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[1183] CFA at pp. 16 ,& 20, Consumers Union at Attachment 4, p. 12, JCCT at pp. 5 &, 6, CARB at p. 214, and States at p.87 each assert that loss aversion is an important source of car buyers' hesitance to purchase higher-mpg models, variously citing Greene, David L., John German, and Mark A. Delucchi, "Fuel Economy: The Case for Market Failure," Reducing Climate Impacts in the Transportation Sector, Springerin James S. Cannon and Daniel Sperling, eds.,,Springer, 2009, at pp. 181-205; (2009);; Greene, David L. (2010).).). How consumers value fuel economy: A literature review (No. EPA–420-R-10-008); Greene, David .L., "Uncertainty, Loss Aversion and Markets for Energy Efficiency", Energy Economics, volvVolvol. 33, at pp. 608-616, (2011);: and Greene, David L., "Consumers' Willingness to Pay for Fuel Economy: Implications for Sales of New Vehicles and Scrappage of Used Vehicles," attachment to comments by CARB, Oct. 10, 2018. However, none of these sources presents empirical evidence on how the frequency of actualcommon loss aversion actually is among real world vehicle buyers, instead simply asserting (or implicitly assuming) that loss aversionit is likely to be widespread. Further, their (identical) estimates of the *degree* of loss aversion are difficult to trace, and appear to be drawn from classroom exercises administered to limited numbers of university students, not from empirical research, involving real world vehicle buyers. One source cited for their repeated assertion that losses of a given dollar amount are valued twice as highly as gains of the same amount is Gal, David, "A psychological law of inertia and the illusion of loss aversion," Judgment and Decision Making, Vol. 1, No. 1, at pp. 23-32 (July 2006.), pp. 23–32, but this reference does not report such a value. Another source repeatedly cited by Greene and co-authors, Benartzi, Shlomo, and Richard H. Thaler, "Myopic Loss Aversion and the Equity Premium Puzzle," Quarterly Journal of Economics, Vol. 110, No. 1, at pp. 73-92 (February 1995), pp. 73-92, does report this value (at p. 74), although only in passing, and cites other references as its original source. The original sources of the claim that losses are values twice as highly as equivalent gains appear to be Kahneman, Daniel, Jack L. Knetsch, and Richard H. Thaler, "Experimental Tests of the Endowment Effect and the Coase Theorem," Journal of Political Economy, Vol. 98, No. 6., , pp. 1325-48 , (Dec., 1990) (, pp. 1325-1348, specifically Section II) , pp. 1329-1336; and Tversky, Amos, and Daniel Kahneman, "Loss Aversion in Riskless Choice: A Reference-Dependent Model," Quarterly Journal of Economics, Vol. 106, No. 4, at pp. 1039-61 (Nov., 1991) (, pp. 1039-1061, specifically pp. 1053-1054). Neither of these references, however, makes any claim about the generality of the estimate or its applicability to non-experimental settings for consumer behavior.

[1184] *See* Gal, David, "A psychological law of inertia and the illusion of loss aversion," Judgment and Decision Making, Vol. 1, No. 1, PPpp. 23-32 (July 2006.) pp. 23–32.; Erev, I., E. Ert, and E. Yechiam, "Loss aversion, diminishing sensitivity, and the effect of experience on repeated decisions,.", Journal of Behavioral Decision Making, Vol. 21 (2008), pp. 575–597; (2008);; Ert, E., and I. Erev, "On the descriptive value of loss aversion in decisions under risk: Six clarifications," Judgment and Decision Making, Vol. 8 (2013), at pp. 214–235; (2013);; Gal, David and Rucker, Derek, "The Loss of Loss Aversion: Will It Loom Larger Than Its Gain?"?", Journal of Consumer Psychology, Vol. 28 No. 3, (July 2018), at pp. 497-516 (July 2018) available at (https://onlinelibrary.wiley.com/doi/abs/10.1002/jcpy.1047); and Gal, David, "Why the Most Important Idea in Behavioral Decision-Making Is a Fallacy," Scientific American, Observations, (July 31, 2018), available at (https://blogs.scientificamerican.com/observations/why-the-most-important-idea-in-behavioral-decision-making-is-a-fallacy/).

Turrentine and Kurani, which relies on interviews with a limited number of subjects, a mere 57 California households, to conclude that consumers are generally unable to perform the calculations necessary to estimate the value of fuel savings.[1185] At the same time, these commenters ignore the wealth of detailed, publicly-available information on the fuel economy of new vehicle models, and shoppers' ready access to user-friendly tools to estimate the savings they are likely to realize from purchasing higher-mpg models- including the label that prominently spells this out, in color and, in large font (*see* Figure VI-39), which is legally required to be prominently displayed on all new cars vehicles offered for sale.[1186] Separately, new car dealers are required to prominently to display the Federal Fuel Economy Guide for each model year of new vehicles offered for sale, which provides fuel economy information for all vehicles from that model year.[1187]

[1185] ICCT at p. 4 and Consumers Union at p. 12 (among others) , citeciteing Turrentine, T. S., & Kurani, K. S., "Car buyers and fuel economy?"", *Energy policy*, *Vol. 35 No. 2 (2007), at pp.* 1213-1223, available at . (2007).. https://www.sciencedirect.com/science/article/pii/S0301421506001200, as evidence that new-car shoppers are generally incapable of calculating the savings they would realize from purchasing a higher-mpg model, and further misinterpret the study as evidence that buyers invariably underestimate the value of increased fuel economy. Yet this widely relied-upon analysis included only 57 households, all located in California. As an illustration, citing Turrentine and Kurani, ICCT asserts "There is substantial circumstantial evidence that *most consumers in the U.S.* place a low value on fuel economy.." ICCT at 4 (emphasis added). *See* ICCT. ." (p. 4, (, emphasis added).) Similarly, Consumers Union asserts "Households do not track gasoline prices over time and cannot accurately estimate future gas
prices or cost savings." See Consumers Union at, (p. 12 (), again citing Turrentine and Kurani as authority).

[1186] *See* 15 U.S.C. 1531, *et seq.*, and 49 CFR 575.401.

[1187] 40 CFR 600.405-08 and 600.407-08.

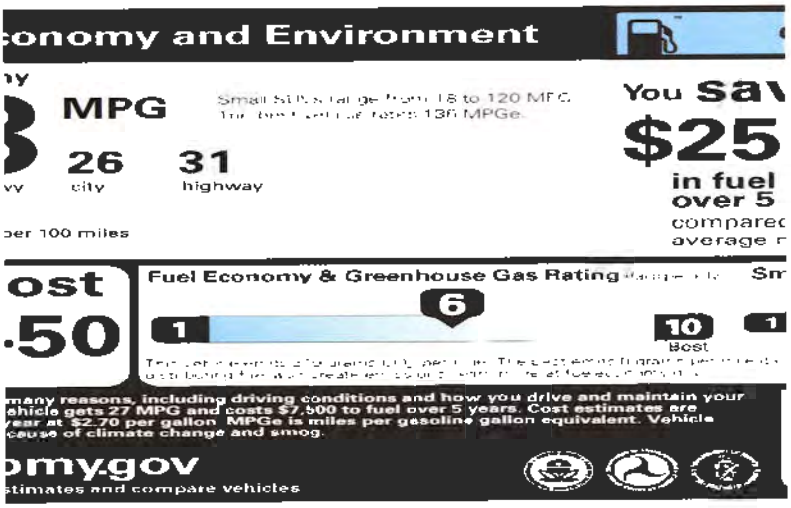

Figure VI-39 - Fuel Economy and Environment Label Example

Similarly, no commenters offer evidence to support their assertion that buyers or the public actually view features such as styling, size, or performance as "positional goods" to which other potential buyers might aspire, or consider the possibility that high fuel economy or advanced technology (such as hybrids or electric vehicles) might *themselves* represent such positional attributes.[1188] Nor do commenters provide evidence of the extensiveness or empirical significance that of the aspects of behavior they allege lead buyers to underinvest in fuel economy, such as unwillingness to spend time or effort estimating likely fuel savings, inattentiveness to the economic and social importance of improved fuel economy, inability to

[1188] For evidence that prestige appears to be a motivation for purchasing advanced-technology vehicles, see Hidrue, Michael K., et al., "Willingness to pay for electric vehicles and their attributes," Resource and Energy Economics, Vol. 33, Issue 3 (September 2011), at pp. 686-705; Chua, Wan Ying, Lee, Alvin and Sadeque, Saalem 2010, "Why do people buy hybrid cars?," Proceedings of Social Marketing Forum, University of Western Australia, Perth, Western Australia, Edith Cowan University, Churchlands, W.A., at pp. 1-13; Liu, Yizao, "Household demand and willingness to pay for hybrid vehicles," Energy Economics, Volume 44, 2014, at pp. 191-197; Hur, Won-Moo, Jeong Woo, and Yeonshim Kim, "The Role of Consumer Values and Socio-Demographics in Green Product Satisfaction: The Case of Hybrid Cars," Psychological Reports, Volume 117, issue 2, October 2015, at pp. 406-427. A useful summary of many studies appears in Table 1 (p. 196) of Makoto Tanaka, Takanori Ida, Kayo Murakami, Lee Friedman, "Consumers' willingness to pay for alternative fuel vehicles: A comparative discrete choice analysis between the US and Japan," Transportation Research Part A: Policy and Practice, Volume 70, 2014, at pp. 194-209 (Table 1 at p. 196). Some of these studies find that buyers are apparently willing to pay significant price premiums for the prestige or status value of hybrids or battery-electric vehicles—which their authors speculate may derive from their "greenness"— because their purchases cannot be explained on the basis of economic or financial considerations. Others find that average or typical shoppers' willingness to pay advanced-technology vehicles is below the price premiums they command, suggesting that their purchasers must derive some status or prestige value from owning and driving them.

obtain information about the savings it offers them, or incorrect "framing" of the choice among models with different levels of fuel economy, are widespread or empirically significant.

The most frequent argument that such a gap exists is the observation that many U.S. vehicle buyers seem unwilling to pay higher prices for models whose increased fuel economy would appear to repay their additional investment within a relatively brief ownership period. Two issues with this argument are readily apparent. First, it does not account for potential sacrifices in *other* vehicle attributes that consumers value, which manufacturers may be forced to make in order to achieve higher fuel economy without increasing vehicles' purchase prices beyond consumers' willingness to pay. Second, those claims unavoidably involve subjective assumptions about consumers' "time preferences," which are revealed by the rates at which they implicitly discount future fuel costs, and thus evaluate savings from purchasing more fuel-efficient models.

Further, even putting these two concerns aside, comparing future fuel savings to the costs of purchasing more expensive models that offer higher fuel economy demonstrates only that buyers are not behaving *as analysts expect them to behave and believe they should behave*. These comparisons do not demonstrate that consumers are necessarily acting irrationally, and such comparisons cannot diagnose the nature of information shortcomings buyers face, reasons that they might interpret such information incorrectly, or behavioral inconsistencies they may exhibit. More important, reciting a catalog of reasons why buyers *might* undervalue potential savings from investing in higher-efficiency vehicle models does not provide evidence that they actually *do so* by their own estimation, and as discussed above, recent research seems to show that such behavior is not widespread, if it exists at all.

Commented [A291]: REVISE: Then why does NHTSA assume that buyers consider only 2.5 years of fuel savings?

Past joint rulemaking efforts by NHTSA and EPA have sought to ~~identify~~ suggest a plausible explanations for car buyers' apparent perceived undervaluation of improved fuel economy. The agencies have occasionally ~~relied on~~ posed explanations such as consumers' insufficient appreciation of the importance of fuel economy, the difficulty of obtaining adequate information about the fuel economy of competing models or of converting competing models' fuel economy ratings to future fuel costs and savings, or consumers' misunderstanding or mistrust of such information when it is provided to them. At other times, the agencies have pointed to consumers' "myopia" about the future—purporting that, for some reason, they consumers appear to underestimate future fuel costs and savings—and argued that shoppers are insufficiently attentive to fuel costs when comparing competing models, that the value of improved fuel economy is obscured ("shrouded") by vehicles' other, more visible attributes, or that uncertainty about the savings in fuel costs owners will actually realize causes them to undervalue those savings when comparing the upfront costs of models with different fuel economy.

Commented [A292]: CHANGE AS SHOWN: EPA does not rely on these arguments. EPA relies on the technical evidence.

Despite the frequency with which the agencies have cited these hypotheses, clear support for these hypotheses for them remains elusive. Consumers have long had ready access to detailed information about individual models' fuel economy, which appears prominently on the

labels displayed by new cars,[1189] and is published in online[1190] and printed outlets that shoppers use routinely rely widely on to compare models. In addition, the fuel economy actually experienced by previous buyers of individual models is increasingly reported in readily accessible on-line databases.[1191]

Similarly, consumers appear to be well aware of the prices they pay for gasoline and how those vary among retail outlets, and are reminded clearly and frequently of the financial consequences of their fuel economy choices each time they purchase fuel. There is also considerable evidence that drivers' forecasts of future fuel prices are more accurate than those issued by government agencies or private forecasting services.[1192] Evidence that car buyers and owners anticipate extreme volatility in fuel prices, recognize that there is considerable uncertainty about future fuel prices and their potential savings from driving a higher-mpg model,

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[1189] Fuel economy labels have been displayed on the window sticker of all new light duty cars and trucks since the mid-1970s, as required by the Energy Policy and Conservation Act. *See* https:.. www.epa.gov/fueleconomy/history-fuel-economy-labeling. Among the information *currently* required to be posted on the fuel economy label is both an estimated annual fuel cost for the vehicle, as well as an estimate of how that cost compares to the fuel cost over five years for an average new vehicle, so it is unclear what information consumers lack that prevents them from making an informed decision in this regard.

[1190] *See, e.g.*, http:.//www.fueleconomy.gov, where consumers can find and compare the fuel economy (CO_2 and smog emissions) of different vehicle models across model years, as well as upload information about their own real-world fuel economy and compare it to other drivers.

[1191] *See id.*

[1192] Anderson *et al.* report evidence that consumers believe fuel prices are likely to remain constant in inflation-adjusted terms.: *sSee* Anderson, Soren T., Ryan Kellogg, and James M. Sallee, "What do consumers believe about future gasoline prices?," Journal of Environmental Economics and Management, vol. 66 no. 3 (2013), at pp. 383-403. (2013).. Other evidence generally supporting this view is reported by Allcott, Hunt, "Consumers' Perceptions and Misperceptions of Energy Costs," American Economic Review: Papers & Proceedings, Vol. 101 No. 3 (2011), at pp. 98 104, (2011),, although Allcott finds that some fraction of consumers consistently believes that gasoline prices will rise in the future. In related research, Anderson *et al.* demonstrate that consumers' expectations that gasoline prices will return to their current levels, even after sudden and significant variation, is generally accurate; *see* Anderson, Soren T., Ryan Kellogg, James M. Sallee, and Richard T. Curtin, "Forecasting Gasoline Prices Using Consumer Surveys.",". American Economic Review: Papers & Proceedings, Vol. 101 No. 3 (2011), at pp. 110-14. (2011).. In contrast to many consumers' expectation that fuel prices may vary over the future but will generally return to current levels, the U.S. Energy Information Administration predicted that gasoline prices would rise significantly over the future at the time the two previous rules establishing CAFÉE standards for model years 2012-16 and 2017-21 were adopted, in 2010 and 2012; see Energy Information Administration (EIA), Annual Energy Outlook 2010), Table A12, p. 131,, available at (https://www.eia.gov/outlooks/archive/aeo10.pdf/0383(2010).pdf), Table A12, p. 131;, and Annual Energy Outlook 2012, Appendix A, Table A12, at p. 155, available at (https://www.eia.gov/outlooks/archive/aeo12/pdf/appa.pdf), Table A12, p. 155. As of those same dates, forecasts of future petroleum prices issued by other government agencies and most private forecasting services (with the notable exception of HIS-Global Insight, which projected little or no increase in future prices) agreed closely with EIA's forecasts that prices would increase significantly over both the near- and longer-term futures; see EIA, Annual Energy Outlook 2010, Table 10, at p. 86; and Annual Energy Outlook 2012, Table 23, available at . (https://www.eia.gov/outlooks/archive/aeo12/table_23.php). Expressed in constant-dollar terms, U.S. gasoline prices in 2019 are essentially unchanged from those in 2010, although prices have varied significantly above and below that level during the intervening period. *See* (https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=emm_epm0_pte_nus_dpg&f=m).

and respond cautiously to these uncertainties when evaluating competing vehicle models[1193] does not suggest a market failure as much as it suggests that consumers balance multiple, often competing objectives, and make choices based on the outcome of such balancing.

In past rulemakings, the agencies have also hypothesized that consumers may "satisfice"—that is, select some minimum acceptable level of fuel economy, and then evaluate models that achieve that minimum on the basis of their other attributes. This explanation for buyers' reluctance to purchase more fuel-efficient vehicles ignores the possibility that they do account fully for the value of higher fuel economy in their decision-making, but simply value differences in vehicles' other attributes more highly than they do fuel economy, which would not reveal irrational or myopic behavior.

A related argument has been that because calculating the future savings from choosing a model that features higher fuel economy is complicated, car shoppers resort to simplified decision rules to choose among models with different fuel economy, and relying on these rules-of-thumb causes them to choose models with lower fuel economy.[1194] However, even if this were true, it is unclear why buyers' reliance on simplified procedures or approximations for estimating the value of fuel savings would necessarily lead them to systematically to choose models with *lower* instead of rather than higher fuel economy, rather than leading some to underinvest in fuel economy while others overinvest.

The agencies have also frequently ~~described~~ raised the possibility that consumers ~~as~~ are "loss averse," making them reluctant to pay the certain higher prices for models offering better fuel economy when the future savings they expect to realize are more distant and less certain.[1195] The agencies' past assumption that loss aversion is universal (and equally strong) among new-car shoppers appears to be a simplification that is largely unsupported by empirical evidence, and in any case has been challenged both as a widespread feature of consumer behavior and more specifically as an explanation for vehicle shoppers' reluctance to purchase more costly models that offer higher fuel economy.[1196] Further, the extremely wide variety of competing models among which car buyers can choose enables many of those searching for a model with better fuel economy at a comparable price to do so simply by choosing a version with fewer other features, which might partly offset the effect of their aversion to the prospect of losses from paying a higher purchase price. Lastly, the agencies note that *both* increased fuel costs and increased upfront car prices will appear as "losses," so it is not obvious why potential buyers would react to them in different ways.

Commented [A293]: CHANGE AS SHOWN: incorrect characterization of EPA's previous discussions.

Commented [A294]: REVISE: This isn't loss aversion. Loss aversion is about risk. Up-front costs are certain and not subject to loss aversion; future fuel savings are uncertain.

[1193] For such evidence, *see* Allcott, Hunt, "Consumers' Perceptions and Misperceptions of Energy Costs," American Economic Review: Papers & Proceedings, Vol. 101 No. 3 (2011), at pp. 98–104; (2011);; Greene, David L...,. (2010). "How consumers value fuel economy: A literature review" No. EPA-420-R-10-008 (2010) (No. EPA-420-R-10-008); Brownstone, David, David Bunch, and Kenneth Train, "Joint Mixed Logit Models of Stated and Revealed Preferences for Alternative-Fuel Vehicles," Transportation Research Part B, Vol. 34 (2000), at pp. 315-338, (2000),, among many other sources.

[1194] *See, e.g.*, 77 FR at 63115 (Oct. 15, 2012).

[1195] *Id.* at 63114-15; *see also* 74 FR at 25511, 25653 (May 7, 2010).

[1196] *See* footnotes 65 and 66 above.

OMB Circular A-4 does mention that "[e]ven when adequate information is available, people can make mistakes by processing it poorly." It goes on to say that people may rely on "mental rules-of-thumb" that produce errors, or cognitive "availability" may lead to consumers overstating the likelihood of an event. However, Circular A-4 also says "the mere possibility of poor information processing is not enough to justify regulation," and that potential problems with information processing "should be carefully documented." Some of the above examples of potential market failures may fall into this category, but lack evidentiary support. As such, similar to claims of asymmetric information, it is very difficult to distinguish between information processing errors and behavior consistent with consumer preferences for time and other vehicle attributes that differ from what some parties believe they should be.

Similarly, the agencies have occasionally noted ~~(and seemingly been critical of)~~ some consumers' apparent preferences for vehicle attributes that convey social status, such as size or styling, and suggested that they may give inadequate attention to fuel economy because it does not provide similar status. The agencies have also suggested that consumers may be reluctant to purchase more fuel-efficient models because they associate higher fuel economy with inexpensive, less well-designed vehicles. These might be plausible explanations, were they not contradicted by concurrent arguments that potential buyers are inattentive to or uninformed about fuel economy, or have difficulty isolating it from vehicles' other attributes. fuel economy from vehicles' other attributes. Moreover, the market currently offers a wide range of highly fuel efficient (and alternative fuel) vehicles at many different price points, including in the luxury and performance segments, which belies the assumption that fuel economy is inconsistent with positional attributes. In any case, consumers' hesitance to choose models offering higher fuel economy because they are reluctant to sacrifice improvements in other vehicle attributes on which they place higher values cannot reasonably be characterized as a market failure.

Commented [A295]: CHANGE AS SHOWN: Inaccurate, and unnecessarily disparaging, assessment of EPA's previous discussions.

Commented [A296]: REVISE: EPA has raised all of these as hypotheses, and has not relied on any one. Thus, their concurrent presentation isn't contradictory.

It does seem contradictory to assume both that consumers are operating rationally and that they consider only 2.5 years of fuel savings.

Commented [A297]: REVISE: This comment seems to indicate that achieving the standards and providing luxury goods are both possible. How does that support the idea that there are tradeoffs between fuel economy and other attributes?

Although the agencies' past rulemakings have discussed the possibility that car buyers' apparent tendency to underinvest in fuel economy could plausibly be explained by their use of discount rates exceeding those the agencies employ to assess the present value of fuel savings, we have generally dismissed that possibility. In combination with factors such as their valuation of vehicles' attributes other than fuel economy, differences in driving habits that affect fuel economy and in how much they expect to drive newly- purchased cars, variation in their expectations about future fuel prices, and tolerance for financial risk, differing attitudes about the importance of future costs relative to more immediate ones could readily explain buyers' apparent reluctance to purchase models offering fuel economy levels the agencies interpret previously interpreted as privately "optimal" choices.

Commented [A298]: REVISE: Higher discount rates is just another way of measuring undervaluation. It hasn't been dismissed.

Finally, the agencies have also frequently speculated that vehicle producers ~~are unwilling to~~ have not offered models featuring the higher levels of fuel economy that buyers are willing to pay for, and that buyers' apparent underinvestment in fuel economy reflects this lack of choice. The agencies have speculated that such behavior by manufacturers could arise from their collective underestimation of the value that buyers attach to fuel economy, or failing this, from limitations on competition among them to supply improved fuel economy, whether voluntarily or as a consequence of the industry's structure.[1197] The agencies have also raised the seemingly

Commented [A299]: CHANGE AS SHOWN: Again, it's an empirical observation that automakers had technologies that, after the standards, were adopted and provided net savings to consumers, without apparent adverse effect on other attributes, and they have been bought. That has not been explained in this discussion.

[1197] *See* 75 FR at 25653-64 (May 7, 2010), *and* 77 FR at 63115 (Oct. 15, 2012).

contradictory argument that producers' more complete knowledge about fuel economy than potential buyers ("asymmetric information") causes them to provide *lower* levels than buyers demand, and speculated that deliberate decisions by manufacturers may limit the range of fuel economy they offer in particular market segments.[1198]

The overarching theme of these arguments seems to be that vehicle manufacturers cannot identify—or can, but voluntarily forego—opportunities to increase sales and profits at the expense of their rivals by offering models that feature higher fuel economy. The agencies have sometimes ascribed this behavior to the risk that producers might incur large investments to produce the more fuel-efficient models that would enable them to seize these opportunities, but subsequently lose sales and profits to competitors who simply followed suit after their rivals were successful. This explanation is at odds with the customary view that innovative producers can be rewarded—even if only temporarily—with commensurate profits that justify taking such risks, at least to the extent the correctly assess consumer demand for that innovation. In any case, behavior on the part of individual businesses that leaves opportunities to increase profits unexploited by an entire industry seems extremely implausible, particularly in light of the fact that auto manufacturers are profit-seeking concerns businesses whose ownership shares are publicly traded and thus subject to regular market valuation. It This notion also flies in the face of the *actual* automobile market, where extraordinarily efficient vehicles are available in every class of vehicle, including the availability of plug-in hybrid or fully electric vehicles. Automobile manufacturers can, and in fact are, competing on the basis of fuel economy.

Commented [A300]: REVISE: See above – it's empirically true that, after the standards, automakers spread the use of existing technologies with short payback periods that they had previously not used. Why hadn't they been in more widespread use before the standards?

Commented [A301]: REVISE: Automakers are competing now, after the standards have been in place for 8 years.

In sum, the agencies do not take a position in this rule on whether a fuel efficiency gap exists and constitutes a failure of private markets. Similarly, the final regulatory impact analysis is not constrained in a manner that would ensure that the private net benefits of more stringent standards would be either positive or negative. Furthermore, the final regulatory impact analysis does not account for the possibility that more stringent standards could require manufacturers to withhold—and thus consumers to sacrifice—other vehicle attributes they value.[1199] If this proved to be the case, more stringent alternatives could impose offsetting losses on buyers well beyond the increases in vehicle prices that are necessary for manufacturers to recover their outlays for adding new technology (or changing design features) to improve fuel economy. By not incorporating this possibility, the analysis supporting this final rule presents the a situation where adopting more stringent CAFE and CO_2 emission standards aligns consumers' decisions with a simplified representation of *their own economic interests*, and by doing so improves their well-being from what they would experience under less stringent standards. In other words, our final modelling results reflect the case where a fuel efficiency gap persists (albeit of smaller magnitude than in previous analyses), despite our reservations about its likelihood.

Commented [A302]: REVISE: This is untrue. The "Performance neutrality" discussion describes how the analysis prevents degradation of other attributes.

[1198] [Text Forthcoming].

[1199] This stance is consistent with the agencies' efforts to hold attributes other than fuel economy and vehicle prices constant at their values under the baseline alternative when evaluating other regulatory alternatives. It simply means that if manufacturers were not required to improve fuel economy further, they might instead elect to improve other features of their vehicle models that buyers find attractive and are willing to pay more for than the required improvements in fuel economy.

b. Representing sales responses in CAFE/ CO_2 analysis

The approach used in the NPRM relied on a single model to produce the total number of new vehicle sales in each calendar year for a given regulatory scenario. Many commenters expressed reservations about the predictive capabilities of the model (CARB, North Carolina Department of Environmental Quality, EDF, Aluminum Association). As the Aluminum Association commented, "[D]eveloping a model to predict consumer reaction to changes in prices is complicated and highly sensitive to macroeconomic conditions, consumer confidence and employment levels."[1200] As discussed above, we agree that development of such a model is complicated, and the agencies have elected to simplify the approach for the final rule. For the purposes of regulatory evaluation, the relevant sales metric is the difference between alternatives rather than the absolute number of sales in any of the alternatives. As such and in response to these comments and others previously addressed, the agencies divided the sales response model for the final rule into two parts: a nominal forecast that provides the level of sales in the baseline (based primarily upon macroeconomic inputs), and a price elasticity that creates sales differences relative to that baseline in each year. The nominal forecast does not include price, and is merely a (continuous) function of several macroeconomic variables that are provided to the model as inputs. While the statistical model used in the NPRM attempted to account for the influence of these other factors in estimating the price elasticity, the forecast in this analysis separates the two completely (as described further below). The price elasticity is also specified as an input, but this analysis assumes a unit elastic response of -1.0—meaning that a one percent increase in the average price of a new vehicle produces a one percent decrease in total sales.[1201]

The revised sales model features three broad changes: 1) it uses the change in average vehicle price net of fuel costs instead of vehicle prices on their own, 2) it uses macroeconomic factors to project baseline sales without considering vehicle prices, and 3) it assesses the change in sales across the various regulatory alternatives considered using an own-price elasticity from the literature. These changes were made in response to comments that consumers are willing to pay for some level of fuel economy and vehicle prices and sales are simultaneously and jointly determined (e.g. endogenous). This section discusses these three broad changes, as well as other more technical and minor changes.

The first component of the new sales response model is the nominal forecast, which is a function (with a small set of inputs) that determines the size of the new vehicle market in each calendar year in the analysis for the baseline. It leverages some of the same structure of the statistical model used in the NPRM, though the dependent variable and some of the explanatory variables have changed. It is of some relevance that this statistical model is intended only as a means to project a baseline sales series. Some commenters raised econometric objections about the NPRM specification's ability to isolate the causal effect of new vehicle prices on new vehicle

[1200] NHTSA-2018-0067-11952-4.
[1201] The "price increase" in this case represents the new vehicle price net of a portion of fuel savings, described further in this section.

sales. The agencies note that the nominal forecast model does not include prices and is not intended for statistical inference.

The forecast is derived from a statistical model that accounts for a similar set of exogenous factors related to new light-duty vehicle sales. In particular, the model accounts for the number of households in the U.S., recent number of new vehicles sold, GDP, and consumer confidence. The structure of the forecast model is similar to the NPRM model, which also used a ARDL specification, but even the variables that are common between the two models have different structural forms in the final rule version. In particular, the dependent variable has been transformed to reflect the fact that, as some commenters suggested, households are an important component of demand for new vehicles. As such, the dependent variable is defined as new vehicles sold per household.[1202] While this variable still exhibits the cyclic behavior that new vehicle sales exhibit over time, the trend shows the number of new vehicles sold per household declining since the 1970's, as shown in Figure VI-40Figure VI-40, where the dotted line is the trend over time. As this time series is non-stationary,[1203] a lagged variable (the value in the previous year) is included on the right-hand side of the regression equation. In Addition, the model includes a lagged variable that represents the three-year running sum of new vehicle sales, divided by the number of households in the previous year. This variable represents the saturation effect, where the existing number of households can only buy so many new vehicles before a significant number of households already have one (and do not need to buy another). As vehicle durability and cost has increased over time, and average length of initial ownership has increased similarly, this variable acts to put downward pressure on sales after successive years of high sales (particularly during extrapolation).

[1202] Number of U.S. households is taken from Federal Reserve Economic data, https://fred.stlouisfed.org/series/TTLHH.

[1203] Stationary refers to whether a time series statistical properties are constant over time. Since car sales are increasing over time, the time series non-stationary.

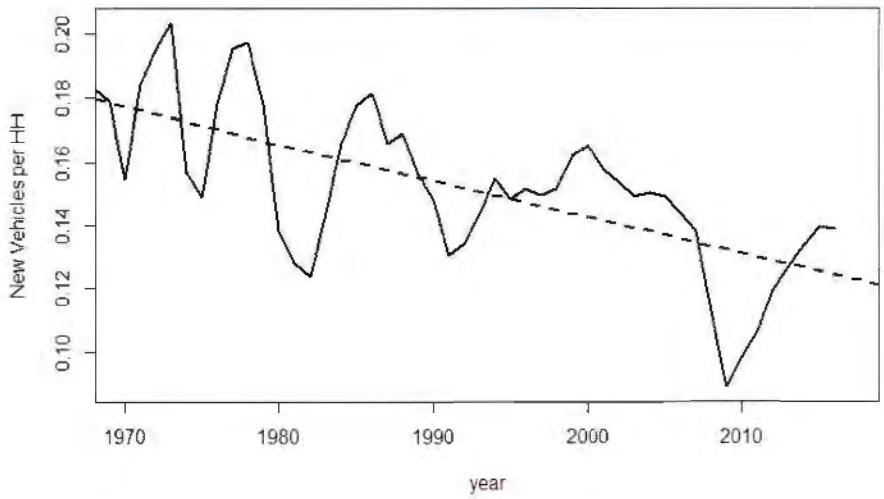

Figure VI-40 - New Light-Duty Vehicle Sales per Household in the United States, 1970 – 2016

Similar to the NPRM model, the forecast model includes real U.S. GDP,[1204] but in natural logarithm form (as some commenters suggested was more appropriate).[1205] The final variable is consumer sentiment, as measured by the University of Michigan survey of consumers.[1206] As both of these series are non-stationary (determined by applying augmented Dickey-Fuller unit root tests to the time series), lagged versions of the variables are included to ensure stationarity in the residuals. The functional form appears below in Equation 1Equation 1.

Equation 1 - Statistical Model Used to Generate Nominal Forecast

$$New_Veh_per_HH_t = C + \beta_1 New_Veh_per_HH_{t-1} + \beta_2 3YrSumPerHH_{t-1} + \beta_3 LN(GDP_t) + \beta_4 LN(GDP_{t-1}) + \beta_5\, Consumer_sentiment_t + \beta_6 Consumer_sentiment_{t-1}$$

The model fit is described in Table VI-92Table VI-92. The included lag term of the dependent variable and both GDP variables are statistically significant at nearly zero, while both the lagged three year sum term and consumer sentiment are both marginally significant. Being a

Commented [A303]: REVISE: Is there any model testing other than looking at the regression results? E.g., were some data withheld to do out-of-sample tests? How do the results compare to other forecasts?

[1204] Federal Reserve Economic Data, available at https://fred.stlouisfed.org/series/GDPC1#0.
[1205] EPA-HQ-OAR-2018-0283-6220-1.
[1206] http://www.sca.isr.umich.edu/tables.html.

time series model, we also computed the Durbin-Watson test statistic for autocorrelation (1.77) and the Breusch-Godfrey test for serial correlation (0.65) at order 1. The signs of the coefficients are all correct, in the sense that they are consistent with our expectations.

Table VI-92 - Summary of Forecast Regression Function

	new.veh.per.HH		
Predictors	*Estimates*	*CI*	*p*
(Intercept)	0.21	0.10 – 0.32	**<0.001**
lag(new.veh.per.HH)	0.70	0.45 – 0.95	**<0.001**
lag(3yrSum.per.HH)	-0.08	-0.16 – 0.01	0.070
LN.Real.GDP	0.44	0.25 – 0.62	**<0.001**
lag(LN.Real.GDP)	-0.45	-0.63 – -0.28	**<0.001**
Cons.sentiment	0.00	-0.00 – 0.00	0.136
lag(Cons.sentiment)	0.00	-0.00 – 0.00	0.948
Observations	47		
R^2 / R^2 adjusted	0.919 / 0.907		

Because the dependent variable is the number of new vehicles sold per household, it is necessary to multiply by the number of households to produce an estimate of new vehicle sales. This model is used to produce a forecast of new vehicle sales out to 2050, so it is necessary to have forecasts of each variable used in Equation 1Equation 1 through calendar year 2050. In an effort to be consistent with other inputs to the analysis, the forecast of U.S. GDP is taken from the 2019 AEO. The forecast of households in this analysis comes from the Harvard Joint Center

for Housing Studies 2018 Household projections.[1207] The consumer confidence forecast is taken directly from the University of Michigan index for 2017 and 2018, and from the Global Insight forecast of consumer confidence for all subsequent years.

While the analysis could have relied on a forecast of new vehicle sales taken from a published source (the 2019 AEO, for example), using a function is an attractive option because it allows the CAFE Model dynamically to adjust the forecast in response to input changes. If a sensitivity case requires a forecast that is consistent with a set of specific, possibly unlikely, assumptions, a forecast of new vehicle sales that is consistent with those assumptions may not exist in the public domain, for example low GDP growth sensitivity cases. Using a functional form, as we have done here, allows the user to vary some of the assumptions to the analysis without creating inconsistencies with other elements of the analysis. However, it is incumbent upon the analyst to ensure that any set of assumptions that deviate from the central analysis are logically consistent.

Commented [A304]: **REVISE:** None of the inputs are likely to be affected by DOT policy, so why does it seem advantageous to be able to adjust inputs?

This function, and the set of assumptions contained in the central analysis, produces a forecast that is comparable in magnitude to the forecast in the 2019 AEO reference case, though there are differences. The two forecasts, and the percentage difference relative to the AEO 2019, appear in Table VI-93Table VI-93, as does a recent forecast published by the Center for Automotive Research.[1208] The reader will notice that even 2017 shows a discrepancy of nearly 7 percent between the final rule forecast and the Annual Energy Outlook, one of the larger differences between annual forecasts. However, the final rule analysis is based upon the certified production volumes of MY2017, which exceed 17 million units. So, while the difference may seem significant, the final rule volumes in 2017 represent the ground truth for model year production.[1209] The CAR forecast, while shorter in length, is consistently higher than both the AEO and final rule forecasts—though likely also includes class 2b (and possibly class 3) pickup trucks in its light vehicle forecast. Finding a public forecast that explicitly excludes light-duty vehicles exempt from these regulations is challenging. However, all three forecasts exhibit similar trends—decreases in sales starting in 2019 that last for a few years before ticking up again slowly. As commenters observed, all forecasts are almost guaranteed to have some errors, and projections out to 2050 should be taken as potential future projections limited by our knowledge at the time, rather than an ironclad prediction of the future.

Table VI-93 - Comparison of AEO2019 Forecast to Final Rule (Million Vehicles)

Year	AEO 2019	Final Rule	Percent difference (AEO, final rule)	CAR
2017	15.95	17.01	6.6	17.2

[1207] https://www.jchs.harvard.edu/research-areas/working-papers/updated-household-growth-projections-2018-2028-and-2028-2038.

[1208] https://www.cargroup.org/u-s-light-vehicle-sales-expected-to-take-a-dip-in-2019/, last accessed 11.21.2019.

[1209] *See* CAFE Public Information Center, https://one.nhtsa.gov/cafe_pic/CAFE_PIC_Home.htm.

2018	15.69	17.10	9.0	17.2
2019	15.66	17.07	9.0	16.8
2020	15.54	16.61	6.8	16.5
2021	15.45	16.04	3.8	16.4
2022	15.10	15.75	4.3	16.8
2023	15.16	15.67	3.4	17.3
2024	15.19	15.76	3.7	17.6
2025	15.19	15.93	4.8	17.7
2026	15.23	16.07	5.5	
2027	15.23	16.20	6.4	
2028	15.28	16.31	6.7	
2029	15.30	16.30	6.5	
2030	15.45	16.35	5.9	
2031	15.69	16.39	4.5	
2032	15.75	16.37	4.0	
2033	15.88	16.40	3.3	
2034	16.04	16.39	2.2	
2035	16.11	16.33	1.4	
2036	16.16	16.28	0.8	
2037	16.26	16.24	-0.1	
2038	16.35	16.22	-0.8	
2039	16.39	16.17	-1.3	
2040	16.45	16.14	-1.9	
2041	16.51	16.08	-2.6	

2042	16.51	16.06	-2.7
2043	16.53	16.04	-2.9
2044	16.63	16.02	-3.7
2045	16.69	16.02	-4.0
2046	16.75	15.97	-4.6
2047	16.74	15.94	-4.8
2048	16.70	15.87	-5.0
2049	16.72	15.80	-5.5
2050	16.72	15.72	-6.0

Although the forecast produces the total number of new vehicle sales in the baseline, an elasticity is imposed on price differences to produce sales changes between alternatives. The NPRM version of the model considered only differences in average new vehicle prices between alternatives, and the agencies received a number of comments (from CBD, IPI, EDF, CARB, CA et al., and Oakland et al., as well as recent peer reviewers) encouraging the agencies to account for some component of fuel savings associated with those price changes. In their comment, California et al. and Oakland et al. stated the model failed "to consider how consumers will respond to the reduced cost of operating the vehicle from better gas mileage and therefore inaccurately predicts a decline in vehicle sales under the existing standards."[1210] The agencies agree that price is not the only consideration, and that the value of fuel savings to new vehicle buyers is also relevant to the purchase decision.

In previous rules, while the agencies produced analyses that qualitatively considered sales and employment impacts, the agencies acknowledged that fuel economy and CO_2 standards were likely to increase vehicle prices, while simultaneously reducing operating costs, and that estimating how consumers would choose to balance those two factors in the new vehicle market was challenging.[1211] Furthermore, the agencies ~~recognized that there is a broad consensus in the economic literature~~ have previously used the stylized fact that the price elasticity of demand for

[1210] NHTSA-2018-0067-11735-73.
[1211] [Text Forthcoming].

automobiles is approximately –1.0.[1212] The agencies feel that a unit elasticity of -1.0 is still a reasonable estimate.[1213]

Commented [A305]: CHANGE AS SHOWN: Perhaps there was a broad consensus 25 years ago, but it's not clear this result still holds.

Because the elasticity assumes no perceived change in the quality of the product, and the vehicles produced under different regulatory scenarios have inherently different operating costs, the price metric must account for this difference. As commenters suggested is appropriate, the price to which the unit elasticity is applied in this analysis represents the residual price change *between scenarios* after accounting for 2.5 years' worth of fuel savings to the new vehicle buyer. This approach is consistent with the 2012 FRIA analysis of sales impacts, that which considered several payback periods over which the value of fuel savings was subtracted from the change in average new vehicle price.

Similar to the NPRM, the price elasticity is applied to the percentage change in average price (in each year). However, the average price to which the elasticity is applied is calculated differently in the final rule in response to comments. As discussed below the price change does not represent an increase/decrease over the last observed year, but rather the percentage change relative to the baseline. In the baseline, the average price is defined as the observed new vehicle price in 2017 plus the average regulatory cost associated with the alternative. In the case of CO_2 standards, the regulatory cost is equivalent to the retail equivalent price of technology improvements. In the case of CAFE standards, the regulatory cost includes both technology costs and civil penalties paid for non-compliance in a model year. So the change in sales for alternative a in year y is:

Equation 2 - Calculation of Change in Sales

$$\Delta Sales_{y,a} = \frac{(\Delta RegCost_{y,a-0} - \Delta FuelCosts_{t,a-0})}{34449 + RegCost_{y,0}} \cdot PriceElasticity \cdot NominalSales_y$$

ΔRegCost is the difference in average regulatory cost between alternative a and the baseline scenario in year y to make a vehicle compliant with the standards, $34,449 is the

[1212] *See, e.g.*, Kleit, A.N., "The Effect of Annual Changes in Automobile Fuel Economy Standards," Journal of Regulatory Economics, Vol. 2 (1990), at pp 151-72; Bordley, R., "An Overlapping Choice Set Model of Automotive Price Elasticities," Transportation Research B, Vol. 28B no. 6 (1994), at pp 401-408; and McCarthy, P.S. "Market Price and Income Elasticities of New Vehicle Demands," The Review of Economics and Statistics, Vol. LXXVII no. 3 (1996), at pp. 543-547.

[1213] For example, a recent review of 12 studies examining vehicle price elasticities conducted by the Center of Automotive Research ("CAR") found an "average short-run elasticity of -1.09" and focusing "only those models which also employ time series methods, the average short-run own-price elasticity is higher yet, at -1.25." CAR's own analysis found a -.79 short-run elasticity. Appendix II of the CAR report shows that the long-run elasticities ranged from -.46 and -1.2 with an average of -.72. In sum, a -1.0 elasticity is well-aligned with the totality of research. McAlinden Ph.D, Sean P., Chen, Yen, Schultz, Michael, Andrea, David J., The Potential Effects of the 2017-2025 EPA/NHTSA GHG/Fuel Economy Mandates of the US Economy, Center for Automotive Research, Ann Arbor, MI (Sept. 2016), available at https://www.cargroup.org/wp-content/uploads/2017/02/The-Potential-Effects-of-the-2017_2025-EPANHTSA-GHGFuel-Economy-Mandates-on-the-US-Economy.pdf.

average transaction price of a new vehicle in 2016, *NominalSales* is the forecasted sales (in the baseline) in year *y*. ΔFuelCosts is the change in average fuel costs over 2.5 years relative to the baseline in year *y* and *PriceElasticity* is -1.0:

Equation 3 - Change in Fuel Costs Used to Compute Sales Differences

$$\Delta FuelCosts_{t,a-0} = \left(\frac{FuelPrice_t}{NewVehFE_{t,a}} - \frac{FuelPrice_t}{NewVehFE_{t,0}}\right) * 35000$$

Where 35,000 miles is assumed to be equivalent to 2.5 years of vehicle usage.[1214] We assume that consumers behave as if the fuel price faced at the time of purchase is the fuel price that they will face over the first 2.5 years of ownership and usage. Essentially, they behave as if fuel prices follow a random walk, where the best prediction of (near) future prices is the price today. Odometer data show that typical usage of new vehicles is about 14,000 miles per year, and that scrappage rates in the first few years of ownership are close to zero, so buyers can reasonably expect to travel the full annual mileage in each of the first three years of ownership. Total sales in each alternative (that is not the baseline) will equal $NominalSales_y + \Delta Sales_{a,y}$ for alternative *a* in year *y*.

Commented [A306]: REVISE: This is inconsistent with (decently lower than) the VMT schedules presented in Tables VI-124 – VI-126.

This implementation produces a range of differences in total sales, both between alternatives and over time. Table VI-94Table VI-94 shows the range of differences in the final rule at the industry level for CO_2, and Table VI-95Table VI-95 shows the sales changes under CAFE. While cost decreases between the baseline and alternatives differ by program, one can see that removing the value of fuel savings from the price limits the sales increases in the alternatives to under 300,000 units in a single year under the preferred alternative, and about one percent of total sales between 2017 and 2050.

Commented [A307]: REVISE: That's not what's actually shown in the tables, is it? This sentence implies that the table shows the impacts of taking fuel savings into account in the calculation, which implies columns showing with & without fuel savings included.

Table VI-94 - Sales Changes Under CO_2 Program

Model Year	Sales and Differences (millions)			Avg Reg Cost and Differences (thousand$)		
	Baseline	0% increase	1.5% increase	Baseline	0% increase	1.5% increase
2017	17.010	0.000	0.000	554	-	-
2018	17.103	0.009	0.008	803	(40)	(39)
2019	17.069	0.028	0.025	1,067	(112)	(100)
2020	16.607	0.065	0.057	1,373	(255)	(224)
2021	16.037	0.117	0.105	1,689	(441)	(399)
2022	15.753	0.201	0.184	2,066	(750)	(680)

[1214] [Text Forthcoming].

2023	15.673	0.227	0.207	2,233	(865)	(781)
2024	15.759	0.272	0.247	2,386	(1,024)	(918)
2025	15.927	0.296	0.264	2,468	(1,120)	(983)
2026	16.071	0.324	0.280	2,578	(1,238)	(1,043)
2027	16.198	0.327	0.277	2,596	(1,276)	(1,046)
2028	16.313	0.317	0.267	2,577	(1,272)	(1,036)
2029	16.303	0.307	0.260	2,549	(1,263)	(1,033)
2030	16.354	0.293	0.250	2,493	(1,221)	(999)
2031	16.390	0.280	0.239	2,441	(1,184)	(970)
2032	16.372	0.269	0.231	2,394	(1,147)	(945)
2033	16.397	0.259	0.223	2,365	(1,112)	(918)
2034	16.389	0.248	0.214	2,338	(1,093)	(903)
2035	16.331	0.238	0.204	2,322	(1,058)	(886)
2036	16.278	0.229	0.197	2,312	(1,033)	(862)
2037	16.244	0.223	0.191	2,296	(1,014)	(846)
2038	16.219	0.215	0.184	2,294	(1,012)	(846)
2039	16.172	0.211	0.180	2,279	(993)	(837)
2040	16.135	0.205	0.174	2,295	(989)	(827)
2041	16.078	0.200	0.170	2,307	(1,002)	(841)
2042	16.058	0.190	0.161	2,310	(999)	(843)
2043	16.040	0.181	0.153	2,369	(1,012)	(855)
2044	16.017	0.176	0.149	2,410	(1,020)	(861)
2045	16.018	0.174	0.147	2,460	(1,010)	(856)
2046	15.970	0.170	0.143	2,520	(975)	(832)
2047	15.939	0.165	0.139	2,545	(955)	(807)

2048	15.866	0.169	0.137	2,560	(930)	(801)
2049	15.797	0.163	0.133	2,641	(965)	(837)
2050	15.722	0.159	0.129	2,685	(961)	(835)
TOTAL	550.611	6.908	5.926			

Table VI-95 - Sales Changes Under CAFE Program

Model Year	Sales and Differences (millions)			Avg Reg Cost and Differences ($)		
	Baseline	0% increase	1.5% increase	Baseline	0% increase	1.5% increase
2017	17.010	0.000	0.000	497	-	-
2018	17.103	0.012	0.010	759	(41)	(36)
2019	17.069	0.027	0.024	1,005	(102)	(92)
2020	16.607	0.041	0.036	1,282	(162)	(145)
2021	16.038	0.095	0.080	1,628	(354)	(299)
2022	15.753	0.174	0.157	1,979	(628)	(560)
2023	15.673	0.207	0.188	2,145	(753)	(671)
2024	15.759	0.275	0.256	2,352	(967)	(884)
2025	15.927	0.306	0.281	2,457	(1,086)	(976)
2026	16.071	0.300	0.271	2,436	(1,074)	(951)
2027	16.198	0.291	0.264	2,408	(1,066)	(948)

2028	16.313	0.279	0.254	2,382	(1,055)	(941)
2029	16.303	0.266	0.242	2,342	(1,034)	(925)
2030	16.354	0.255	0.233	2,298	(1,005)	(899)
2031	16.390	0.243	0.222	2,248	(972)	(870)
2032	16.372	0.231	0.212	2,202	(940)	(842)
2033	16.397	0.221	0.202	2,173	(913)	(819)
2034	16.389	0.211	0.194	2,141	(890)	(798)
2035	16.331	0.202	0.184	2,120	(858)	(775)
2036	16.278	0.191	0.175	2,113	(839)	(756)
2037	16.244	0.184	0.168	2,093	(818)	(736)
2038	16.219	0.178	0.162	2,083	(809)	(727)
2039	16.172	0.172	0.156	2,063	(795)	(712)
2040	16.135	0.158	0.142	2,104	(820)	(729)
2041	16.078	0.151	0.136	2,101	(820)	(728)
2042	16.058	0.145	0.131	2,092	(801)	(711)
2043	16.040	0.139	0.125	2,121	(788)	(698)

2044	16,017	0.134	0.120	2,168	(809)	(708)
2045	16,018	0.134	0.121	2,224	(812)	(716)
2046	15,970	0.129	0.116	2,301	(792)	(700)
2047	15,939	0.125	0.113	2,336	(783)	(693)
2048	15,866	0.123	0.111	2,349	(766)	(683)
2049	15,797	0.121	0.109	2,415	(789)	(710)
2050	15,722	0.120	0.111	2,491	(806)	(726)
TOTAL	550,611	5,839	5,304			

The tables show the regulatory class shares under the baseline (augural standards), proposal (0 percent increase in stringency), and final rule (1.5 percent increase in stringency) of projected sales (and differences for the non-baseline estimates) of MYs 2017-2050.

Dynamic Fleet Share (DFS)

The first module described above (the forecast function and applied elasticity) determine the total industry sales in each model year from 2018 (in this analysis, 2017 is based on certified compliance data) to 2050. A second module, the dynamic fleet share, acts to distribute the total industry sales across two different body-types: "cars" and "light trucks." While there are specific definitions of "passenger cars" and "light trucks" that determine a vehicle's regulatory class, the distinction used in this phase of the analysis is more simplistic. All body-styles that are obviously cars—sedans, coupes, convertibles, hatchbacks, and station wagons—are defined as "cars" for the purpose of determining fleet share. Everything else—SUVs, smaller SUVs (crossovers), vans, and pickup trucks—are defined as "light trucks"—even though they may not be treated as such for compliance purposes. In the case of SUVs, in particular, many models may have sales volumes that reside in both the passenger car and light fleets for regulatory purposes, but the dynamic fleet share does not make this distinction. The fleet share model was applied at the same level in the NPRM. EDF expressed concern that any simulated increase in the light truck share represented consumers shifting from sedans to either 4wheelWD drive crossovers, suvs SUVs or pickup trucks.[1215] However, this was not the case. All crossovers are considered light trucks for the purposes of fleet share, even though they may be 2WD crossovers

[1215] NHTSA-2018-0067-12108-43.

treated as passenger cars for compliance purposes. So, while the number may increase overall for a given scenario, the proportion of crossovers sold as 4WD, rather than 2WD, does not.

EDF was also concerned that the sales implementation in the NPRM, which relied on the absolute average price to determine differences between alternatives, was unduly influenced by fleet share—as differences in the share of light-trucks had the potential to skew differences in average price because light-trucks are generally more expensive than sedans and hatchbacks. The final rule implementation, which starts from an observed average transaction price and evolves the average price in the alternatives based on average regulatory cost, is less vulnerable to this potential distortion. Even if the fleet share model (described in greater detail below) increases the share of light trucks (for example), the inherent price difference between passenger cars and light trucks does not pass through to the average price—only the relative difference in compliance costs associated with the vehicle types. Despite the fact that light trucks have generally higher transaction prices than passenger cars, there is no guarantee that regulatory costs will be higher for light-trucks than for cars (which depend upon the mix of footprints, their distance from the relevant curve, and the technology cost needed to bring each fleet into compliance). Thus, the average price differences used in the sales calculations are relatively unaffected by the fleet share model.

Commented [A308]: **REVISE:** Sales price doesn't show up in the model below.

As in the NPRM, the dynamic fleet share represents two difference equations that independently estimate the share of passenger cars and light trucks, respectively, given average new market attributes (fuel economy, horsepower, and curb weight) for each group and current fuel prices, as well as the prior year's market share and prior year's attributes. The two independently estimated shares are then normalized to ensure that they sum to one. As with the Sales Response model, the DFS utilizes values from one and two years preceding the analysis year when estimating the share of the fleet during the model year being evaluated. For the horsepower, curb weight, and fuel economy values occurring in the model years before the start of analysis, the DFS model uses the observed values from prior model years. After the first model year is evaluated, the DFS model relies on values calculated during analysis by the CAFE model. The DFS model begins by calculating the natural log of the new shares during each model year, independently for each vehicle class, as specified by the following equation:

Equation 4 - Dynamic Fleet Share Equation

$$\ln(Share_{VC,MY}) = \begin{pmatrix} \beta_C \times (1-\beta_{Rho}) + \beta_{Rho} \times \ln(Share_{VC,MY-1}) \\ +\beta_{FP} \times (\ln(Price_{Gas,MY}) - \beta_{Rho} \times \ln(Price_{Gas,MY-1})) \\ +\beta_{HP} \times (\ln(HP_{VC,MY-1}) - \beta_{Rho} \times \ln(HP_{VC,MY-2})) \\ +\beta_{CW} \times (\ln(CW_{VC,MY-1}) - \beta_{Rho} \times \ln(CW_{VC,MY-2})) \\ +\beta_{MPG} \times (\ln(FE_{VC,MY-1}) - \beta_{Rho} \times \ln(FE_{VC,MY-2})) \\ +\beta_{Dummy} \times (\ln(0.423453) - \beta_{Rho} \times \ln(0.423453)) \end{pmatrix}$$

Where:

$\beta_C - \beta_{Dummy}$: set of beta coefficients, as defined by Table VI-96Table VI-96 below, used for tuning the Dynamic Fleet Share model,

$Share_{VC,MY-1}$: the share of the total industry new sales classified as vehicle class VC, in the year immediately preceding model year MY,

$Price_{Gas,MY}$: the fuel price of gasoline fuel, in cents per gallon, in model year MY,[1216]

$Price_{Gas,MY-1}$: the fuel price of gasoline fuel, in cents per gallon, in the year immediately preceding model year MY,

$HP_{VC,MY-1}$: the average horsepower of all vehicle models belonging to vehicle class VC, in the year immediately preceding model year MY,

$HP_{VC,MY-2}$: the average horsepower of all vehicle models belonging to vehicle class VC, in the year preceding model year MY by two years,

$CW_{VC,MY-1}$: the average curb weight of all vehicle models belonging to vehicle class VC, in the year immediately preceding model year MY,

$CW_{VC,MY-2}$: the average curb weight of all vehicle models belonging to vehicle class VC, in the year preceding model year MY by two years,

$FE_{VC,MY-1}$: the average on-road fuel economy rating of all vehicle models (excluding credits, adjustments, and petroleum equivalency factors) belonging to vehicle class VC, in the year immediately preceding model year MY,

$FE_{VC,MY-2}$: the average on-road fuel economy rating of all vehicle models (excluding credits, adjustments, and petroleum equivalency factors) belonging to vehicle class VC, in the year preceding model year MY by two years,

0.423453 : a dummy coefficient, and

$\ln(Share_{VC,MY})$: the natural log of the calculated share of the total industry fleet classified as vehicle class VC, in model year MY.

Commented [A309]: REVISE: Beta rho needs a definition, not just a value, given its key role in the above equation.

Commented [A310]: REVISE: Beta is the coefficient (see above definition of beta). This definition doesn't make sense. Dummy variables are 0 or 1, and have particular meanings.

In the equation above, the beta coefficients, β_C through β_{Dummy}, are provided in the following table. The beta coefficients differ depending on the vehicle class for which the fleet share is being calculated.

[1216] As discussed elsewhere in this final rule, model year and calendar year are assumed to be equivalent in the simulation—as they always have been in all prior rulemaking analyses.

Table VI-96 - DFS Coefficients

Coefficient	Car Value	Light Truck Value
β_C	3.4468	7.8932
β_{Rbu}	0.8903	0.3482
B_{FP}	0.1441	0.4690
B_{HW}	-0.4436	1.3607
B_{CW}	-0.0994	1.5664
B_{MPG}	-0.5452	0.0813
B_{Dummy}	-0.1174	0.6192

Once the initial car and light truck fleet shares are calculated (as a natural log), obtaining the final shares for a specific vehicle class is simply a matter of taking the exponent of the initial value, and normalizing the result at one (or 100%). This calculation is demonstrated by the following:

Equation 5 - Normalizing individual fleet shares

$$Share_{VC,MY} = \frac{e^{\ln(Share_{VC,MY})}}{e^{\ln(Share_{LDV,MY})} + e^{\ln(Share_{LDT1/2a,MY})}}$$

Where:

$\ln(Share_{VC,MY})$: the natural log of the calculated share of the total industry fleet classified as vehicle class *VC*, in model year *MY*,

$\ln(Share_{LDV,MY})$: the natural log of the calculated share of the total industry fleet classified as light duty passenger vehicles (LDV), in model year *MY*,

$\ln(Share_{LDT1/2a,MY})$: the natural log of the calculated share of the total industry fleet classified as class 1/2a light duty truck (LDT1/2a), in model year *MY*, and

$Share_{VC,MY}$: the calculated share of the total industry fleet classified as vehicle class *VC*, in model year *MY*.

These shares are applied to the total industry sales derived in the first stage of the sales response. This produces total industry volumes of car and light truck body styles. Individual model sales are then determined from there based on the following sequence: 1) individual manufacturer shares of each body style (either car or light truck) times the total industry sales of that body style, then 2) each vehicle within a manufacturer's volume of that body-style is given the same percentage of sales as appear in the 2017 fleet. This implicitly assumes that consumer preferences for particular styles of vehicles are determined in the aggregate (at the industry level), but that manufacturers' sales shares of those body styles are consistent with MY2017

sales. Within a given body style, a manufacturer's sales shares of individual models are also assumed to be constant over time. We assume that manufacturers are currently pricing individual vehicle models within market segments in a way that maximizes their profit. Without more information about each OEM's true cost of production and operation, fixed and variables costs, and both desired and achievable profit margins on individual vehicle models, we have no reason to assume that strategic shifts within a manufacturer's portfolio will occur in response to standards.

The Global Automakers noted in their comments that the market share of SUVs continues to grow, while conventional passenger car body-styles continue to lose market share.[1217] The agencies are aware of this, and include the DFS model in an attempt to address these market realities. In the 2012 final rule, the agencies projected fleet shares based on the continuation of the baseline standards (MY2012-2016) and a fuel price forecast that was much higher than the realized prices since that time. As a result, that analysis showed passenger car body-styles comprising about 70 percent of the new vehicle market by 2025. The reality, as Global Automakers note, has been quite different.

The coefficients of the DFS model show passenger car styles gaining share with higher fuel prices and losing them when prices are lower. Similarly, as fuel economy increases in light truck models, which offer consumers other desirable attributes beyond fuel economy (ride height or interior volume, for example) their relative share increases. NRDC, in particular, found this counterintuitive.[1218] However, this approach does not suggest that consumers *dislike* fuel economy in passenger cars, but merely recognizes the fact that fuel economy has diminishing returns. As the fuel economy of light trucks increases, the tradeoff between passenger car and light truck purchases is increasingly involves a consideration of other attributes. Similarly, the coefficients show a relatively stronger preference for power improvements in cars than light trucks because that is an attribute where trucks have outperformed cars, like cars have outperformed trucks for fuel economy.

Commented [A311]: REVISE: This says that that fuel economy improves ride height and interior volume. That isn't right.

Rather than estimate new functions ourselves, we applied existing functions from the transportation module of the National Energy Modeling System (NEMS) that was used to produce the 2017 Annual Energy Outlook. The functions above appear in the "tran.f" input file to that version of NEMS, and were embedded (in their entirety) in the CAFE model in the NPRM (and this final rule). NEMS uses the functions to estimate the percent of total light vehicles less 8,500 GVW that are cars/trucks. While NRDC asserted that the agencies must demonstrate the propriety of the fleet share model before relying on its estimates,[1219] they ignore the fact that, by using the AEO to develop a static fleet in prior rulemakings, the agencies have always relied on NEMS estimates. The primary difference between those analyses and the NPRM (and this final rule), is that prior analyses applied the fleet share that was simulated for the baseline to all regulatory scenarios considered. Based on the fleet share functions in NEMS, NPRM corrected this internal inconsistency found in previous analyses. This approach also enables consistent sensitivity cases—where higher fuel prices produce fleets with more

[1217] NHTSA-2018-0067-12032-25.
[1218] NHTSA-2018-0067-11723-27.
[1219] NHTSA-2018-0067-11723-27.

transitional passenger car body styles, for example—and ensures that the starting point (MY2017) evolves in response to both fuel economy improvements and fuel prices in a way that is internally consistent.

The agencies are making one change to the DFS function, which is the level of application. While NEMS intended the fleet shares to be defined by regulatory classes, vehicles are defined much more coarsely in NEMS than in the CAFE model, and manufacturers are not differentiated at all. In order to produce well-behaved fleet share projections with this model, we applied the share functions to body-styles rather than regulatory classes. For many years, there was little overlap between nameplates in a manufacturer's passenger car regulatory class and its light truck regulatory class. However, with the recent emergence of smaller FWD SUVs and crossovers, it is increasingly common to have nameplates with model variants in both the passenger car and light truck regulatory classes, and it is also common for there to be only minor differences (like the presence of 4WD or AWD) between versions regulated as cars and versions regulated as light trucks. We have modified the application of the fleet share equations to focus on body-style, rather than regulatory class, in recognition of the increased ambiguity between the regulatory class distinction for popular models like the Honda CR-V and Toyota RAV4, that sell more than 100K units in each regulatory class (typically using the same powertrain configuration). The Nissan Rogue sold more than 400K units in MY2017, and almost exactly half of them were in the light truck (LT) regulatory class. Applying the fleet share at the body-style level preserves the existing regulatory class splits for nameplates that straddle the class definitions. It also serves to minimize the deviation from the observed MY2017 regulatory class shares over time. Had we applied the share equations at the regulatory class level, as some commenters incorrectly claimed the agencies were doing in the proposal, the passenger car regulatory class would have eroded much faster than we've seen in the real world and ceased to resemble the composition of the MY2017 fleet. Our implementation allows the passenger car (PC) regulatory class to continue evolving toward crossover-type cars, if that is what economic and policy conditions favor.

Commented [A312]: REVISE: Redundant with p. 535, intro to this section.

Table VI-97 - Regulatory Class Shares Under CAFE[1220]

Model Year	Baseline		0% Increase		1.5% Increase	
	PC	LT	PC	LT	PC	LT
2017	0.53	0.47	0.53	0.47	0.53	0.47
2018	0.53	0.47	0.53	0.47	0.53	0.47
2019	0.53	0.47	0.54	0.46	0.54	0.46
2020	0.54	0.46	0.54	0.46	0.54	0.46

[1220] The "passenger car" fleet for CAFE represents the combination of both imported passenger cars (IC) and domestic cars (DC). While Table VI-97Table VI-97 illustrates shares for the CAFE program, resulting shares under the tailpipe CO_2 emissions standards are comparable.

2021	0.54	0.46	0.54	0.46	0.54	0.46
2022	0.53	0.47	0.54	0.46	0.54	0.46
2023	0.53	0.47	0.54	0.46	0.54	0.46
2024	0.53	0.47	0.54	0.46	0.54	0.46
2025	0.53	0.47	0.55	0.45	0.55	0.45
2026	0.53	0.47	0.55	0.45	0.55	0.45
2027	0.53	0.47	0.55	0.45	0.55	0.45
2028	0.54	0.46	0.55	0.45	0.55	0.45
2029	0.54	0.46	0.56	0.44	0.55	0.45
2030	0.54	0.46	0.56	0.44	0.56	0.44

Table VI-97Table VI-97 shows the regulatory class shares under the baseline (augural standards), proposal (0 percent increase in stringency), and final rule (1.5 percent increase in stringency) between 2017 and 2030. The shares move relatively little between the classes in the baseline, with larger (but still small) deviations occurring in the least stringent alternative (0 percent increase) and the final rule. As the sensitivity cases show, the changes in shares (both over time and between regulatory classes) respond to the fuel price case, but remain internally consistent due to the inclusion of the DFS.

Some commenters encouraged the agencies to consider vehicle attributes beyond price and fuel economy when estimating a sales response to fuel economy/CO_2 standards, and suggested that a more detailed representation of the new vehicle market would allow the agencies to simulate strategic mix shifting responses from manufacturers and diverse attribute preferences among consumers. Doing so would have required a discrete choice model (at some level), and we describe below the reasons why we have not chosen to employ that approach in this final rule.

Commented [A313]: REVISE: Price isn't in the DFS model.

c. Using vehicle choice models in rulemaking analysis

[Text Forthcoming]

(3) Scrappage

(a) The Impacts of New Vehicle Fuel Economy Standards on Fleet Turnover

Economic literature and theory indicate that the retirement (or scrappage) rates of existing vehicles slows when new vehicle fuel economy standards increase and cause new vehicle price increases. Slower retirement rates result in an older distribution of the on-road fleet. Today's on-road fleet is the oldest it has ever been, approaching an average of 12 years old.[1221] Since older vehicles are, on average, less safe and less fuel efficient, modeling this reduction in the scrappage rates of existing vehicles has important implications. As mentioned in the sales section above, past quantitative analyses of CO_2 and CAFE standards excluded the scrappage effect (though the agencies discussed the scrappage effect qualitatively), which could have resulted in an overestimate of the benefits of increasing standards.

Commented [A314]: **REVISE:** Yes due to price increases, but improvements in fuel economy of new vehicles increase scrappage, all else equal.

Commented [A315]: **REVISE:** Doesn't that have more to do with improved vehicle durability than with fuel economy/GHG standards?

For the NPRM, the agencies chose for the first time to model quantitatively the change in existing vehicle retirement rates across regulatory alternatives. The agencies used a logistic function to estimate the instantaneous scrappage rate for vehicles of different body styles and model year vintages using registration data from Polk, the estimated durability of specific model year vintages, the prices of new vehicles, a measure of the cost of travel for the model year cohort versus new vehicles in any given calendar year, and other cyclical macroeconomic indicators.[1222]

The agencies received many comments about the NPRM's scrappage model. While some commenters objected to the inclusion of a scrappage model, most commenters supported the inclusion of a dynamic scrappage model as an improvement in the agencies' analysis; these comments are discussed in Section I.A.1.a)(1)(a)(ii). Other commenters raised concerns about the specific scrappage models used in the NPRM analysis; these are discussed in Section I.A.1.a)(1)(b). Specifically, commenters raised concerns about overfitting in the models, the identification strategy, the modeling of new and used vehicle fuel economy in general, the exclusion of certain variables, about how the agencies captured macroeconomic effects, and about the lack of integration with the sales model.

The agencies contemplated all of the comments and suggestions made by commenters and, in response, have made several changes to final rule's model. First, we changed the time-series strategy used in the model, as discussed in Section I.A.1.a)(1)(c)(iii)(a). This change allows the agencies to simplify the models significantly, addressing commenters' concerns about potential overfitting of the model and difficulty of interpreting individual coefficient values (discussed in Section I.A.1.a)(1)(b)(i)). Second, the agencies changed the modeling of the durability effect as discussed in Section I.A.1.a)(1)(c)(iii)(c); this change reduces the reliance on the decay function and has the added benefit of addressing concerns about overfitting and out-of-sample projections discussed in Section I.A.1.a)(1)(b)(i). Third, a portion of anticipated fuel savings from increased fuel economy are netted from new vehicle prices—meaning consumers are now assumed to value fuel economy at the time of purchase to a certain extent—as discussed in Section I.A.1.a)(1)(c)(iii)(d). This change is in response to comments discussed in Section

[1221] [Text Forthcoming].

[1222] For a more detailed explanation of the NPRM model, *see* PRIA Chapter 8.10.

I.A.1.a)(1)(b)(ii) and addresses inconsistent treatment of consumer valuation within the NPRM's analysis. Finally, we consider the inclusion of additional or alternative variables in the scrappage model in response to comments discussed in Section I.A.1.a)(1)(b)(iii). After extensive testing, the agencies concluded that these additional variables do not improve the model fits or would introduce autocorrelation in the error structures (see Sections I.A.1.a)(1)(c)(iii)(e) and I.A.1.a)(1)(c)(iii)(f) for further discussion). As such, the agencies rejected the additional terms suggested by commenters. Input from commenters was used to simplify the scrappage model, make it more consistent with modeling of new vehicle prices elsewhere in the analysis, and improve its predictions for the instantaneous scrappage rates of vehicles beyond age 20.

(i) Basis for 'The Gruenspecht Effect'

Gruenspecht (1981) and (1982) recognized that since fuel economy standards affect only new vehicles, any increase in price (net of the portion of reduced fuel savings valued by consumers) will increase the expected life of used vehicles and reduce the number of new vehicles entering the fleet. The effects of differentiated regulation in the context of fuel economy is often deemed the *Gruenspecht Effect*.[1223] Jacobsen and van Bentham (2015) first quantified the Gruenspecht Effect, or the share of new vehicle fuel savings lost to the used vehicle fleet due to delayed scrappage, to be between 13 and 16 percent.[1224]

Commented [A316]: REVISE: The concept was introduced in the context of criteria pollutants, not fuel economy.

As discussed in Section [xxx], fuel economy standards increase the cost of acquiring new vehicles, but also improve the quality of those vehicles by increasing their fuel economy. The CAFE analysis assumes that consumers value 30 months of fuel savings, so that the quality-adjusted change in new vehicle prices is the increase in regulatory costs less 30 months of fuel savings. As long as the quality-adjusted price is positive,[1225] it becomes more expensive for manufacturers to produce vehicles and, as a result, prices of new vehicles increase. From a supply and demand perspective, this equates to the supply curve for new vehicles moving inwards or to the left and a corresponding increase in the equilibrium price and decrease in the equilibrium quantity of new vehicles purchased.

New and used vehicles are substitutes. When the price of a good's substitute increases, the demand curve for that good shifts upwards and the equilibrium price and quantity supplied also increases. Thus, increasing the quality-adjusted price of new vehicles will result in an increase in equilibrium price and quantity of used vehicles. Since, by definition, used vehicles are not being "produced" but rather "supplied" from the existing fleet, ~~the~~ any increase in quantity must come via a reduction in their scrappage rates. Practically, when new vehicles become more expensive, used vehicles also become more popular (and more expensive). Because used vehicles are more valuable in such circumstances, they are scrapped at a lower rate, and just as rising new vehicle prices push marginal prospective buyers into the used vehicle

Commented [A317]: REVISE: It's not technically true that quantity has to increase; the supply curve could be vertical.

[1223] Gruenspecht, H. "Differentiated Regulation: The Case of Auto Emissions Standards." American Economic Review, Vol. 72(2), pp. 328-331 (1982).
[1224] M. Jacobsen and A. van Benthem, "Vehicle Scrappage and Gasoline Policy," *American Economic Review*, Vol. 105, pp. 1312-38 (2015).
[1225] The quality adjusted price is positive when regulatory compliance costs exceed 30 months of fuel savings.

market, rising used vehicle prices force marginal prospective buyers of used vehicles to acquire older vehicles or vehicles with fewer desired attributes.

(ii) Commenter Response to the Inclusion of the Gruenspecht Effect

(a) Many Commenters Support the Inclusion of the Effect

Commented [A318]: REVISE: Section should include discussion of peer review commenters.

Academic researchers and automakers widely agree with the existence and direction of the Gruenspecht Effect. For example, RFF commented, "There's good evidence supporting the scrappage effect."[1226] The Auto Alliance stated that the agencies "made significant strides toward improving their modeling of consumer behavior by adding new modules to estimate new vehicle sales and in-use vehicle scrappage in response to changes to new vehicle prices."[1227] FCA agreed "that an outcome of the current augural stringency of the CAFE/[CO_2] emission regulations may be a decreasing trend in vehicle scrappage rates as consumers delay purchases [...] forc[ing] consumers to hold their current vehicles for additional time."[1228]

Other commenters agreed with the existence of the effect, but took issue with the implications of the combination of the sales and scrappage models. Mark Jacobsen stated "while we agree that the scrappage effects we study will mitigate changes in the used fleet, we do not believe they could be strong enough to reverse completely the direction of change in the used fleet."[1229] Jacobsen's contention was echoed by many commenters; the main point was that they believed that the prices of both new *and* used vehicles should be less expensive in the NPRM's preferred alternative than the augural standards, and that this should, if anything, result in a larger fleet in the NPRM's preferred alternative. This issue is further discussed in Section (b)(iv) with other comments about integrating the sales and scrappage models and the incremental fleet size across alternatives. Here it is important to note that this concern does not suggest that *a* scrappage model *should not exist*, but takes issue with the *specific modeling* of scrappage and/or sales implemented in the NPRM analysis.

(b) Some Commenters Worry about the Shift in Agency Perspective

Some commenters argued that the agencies modeling of sales and scrappage in the NPRM analysis contradicted previous positions that these effects were too uncertain to model. For example, the Center for Biological Diversity (CBD) commented:

> In the 2012 rulemaking for fuel economy and [CO_2] standards, both NHTSA and EPA stated that analysis of the standards' impact on new vehicles sales and on the "scrappage" of used vehicles was too uncertain to be used in the rulemaking. The agencies reiterated this position in their 2016 technical assessment of the standards.

[1226] [Text Forthcoming].
[1227] [Text Forthcoming].
[1228] [Text Forthcoming].
[1229] [Text Forthcoming].

They further stated:

> The agencies have not provided a meaningful rationale or justification for the change in position regarding their ability to present quantified estimates of the impact of the standards on new vehicle sales and the scrappage of used vehicles.

To respond to these comments, it is useful to look at the reasons the agencies gave for not considering fleet turnover effects on pages 845-46 of the 2012 rulemaking[1230]:

> If the value of fuel savings resulting from improved fuel efficiency to the typical potential buyer of a new vehicle outweighs the average increase in new models' prices, sales of new vehicles will rise, while scrappage rates of used vehicles will increase slightly. This will cause the "turnover" of the vehicle fleet—that is, the retirement of used vehicles and their replacement by new models—to accelerate slightly, thus accentuating the anticipated effect of the rule on fleet-wide fuel consumption and CO_2 emissions. However, if potential buyers value future fuel savings resulting from the increased fuel efficiency of new models at less than the increase in their average selling price, sales of new vehicles will decline, as will the rate at which used vehicles are retired from service. This effect will slow the replacement of used vehicles by new models, and thus partly offset the anticipated effects of the final rules on fuel use and emissions.
>
> *Because the agencies are uncertain about how the value of projected fuel savings from the final rules to potential buyers will compare to their estimates of increases in new vehicle prices, we have not attempted to estimate explicitly the effects of the rule on scrappage of older vehicles and the turnover of the vehicle fleet.*

The agencies' reason for not modeling the fleet turnover effects in prior rulemakings was not uncertainty about the direction or impact of vehicle prices on sales or scrappage rates, but rather uncertainty about how consumers value fuel savings. As explained in section [xxx], the agencies now have sufficient knowledge regarding the amount of fuel savings consumers are assumed to value at the time they purchase new vehicles. With this assumption, it becomes possible to model the fleet turnover effects, including the scrappage effect.

Commented [A319]: REVISE: The decision to use 2.5 years of fuel savings is not well supported by the data. It's within the (very wide) bounds of estimates in the academic literature, but very far below the estimates from the 3 more recent papers cited starting on p. 507 of the current draft.

(c) Some Commenters Think the Effects Are Uncertain

Other commenters argue that the sales and scrappage effects are too uncertain to include in a rulemaking analysis. For example, CBD argued that "the models are attempting to evaluate the small and uncertain effects of changes in vehicle standards on certain dynamics—vehicle sales, scrappage rates, and vehicle usage—which are largely determined by much stronger forces, such as the state of the economy."[1231]

[1230] [Cite: 2012 FRM (Emphasis added.)].
[1231] [Text Forthcoming].

The agencies agree that there is uncertainty around the magnitude of the sales and scrappage response, but do not agree that sign of either effect is uncertain. Importantly, excluding modeling of the sales and scrappage effects would only make sense if there was a legitimate existential concern—the sales and scrappage effects are founded in very basic economic theory, as noted above in Section [xxx]. Furthermore, the agencies believe that assessing the magnitudes of the sales and scrappage effects is a tractable task for researchers and sufficient data exists to quantify these effects. Thus, excluding these effects would be a serious omission that limits accurate accounting of the costs and benefits of fuel economy standards. Other stakeholders commented that the NPRM analysis did not thoroughly consider the uncertainty around the magnitudes of the sales and scrappage responses. These comments and the agencies response is discussed in Section I.A.1.a)(1)(b)(i), below. The agencies believe it is better to consider a range of the scrappage and sales response to address concerns about uncertainty, and that excluding them would be inappropriate.[1232] The agencies did just that with the proposal through sensitivity analyses including seeking comment and having the scrappage modeling peer reviewed—and continue to do so for the final rule.

Commented [A320]: **REVISE:** It's highly uncertain in the sense that there isn't a consensus around the role of fuel economy in these decisions, and the value of fuel savings might well be higher than the technology costs. In addition, the relationship between new & used vehicle markets is not well studied. Thus, the sign is in fact uncertain.

(b) Summary of Notice, Request for Comments, and the Agencies' Response

The comments related to the scrappage model are summarized here into five major categories: overfitting and identification strategies, modeling fuel economy and new vehicle prices, consideration of other additional variables, integration with sales or VMT, and evaluations of associated costs and benefits due to changes in scrappage rates within the CAFE model. Specific modeling decisions the agencies have made or considered in response to the public comments summarized in this section are discussed in Sections I.A.1.a)(1)(c)(ii)(d) and I.A.1.a)(1)(c)(iii).

Commented [A321]: **REVISE:** What about the fundamental concern that the results did not comport with economic theory? – lower vehicle prices for both new & used vehicles leading to a smaller vehicle fleet.

(i) Overfitting and Identification Strategy

Several commenters argued that the NPRM scrappage model did not have a clear identification strategy, or that the model *over-fit* the data. These commenters suggest that the NPRM model may not capture a causal relationship, but picks up other correlation or noise within the data. This section outlines the specific claims made by commenters.

(a) Overfitting and the Use of Lagged and Interactions Terms

Several commenters argued that the results presented in the NPRM could be driven by the specific structure of the price effect used in the scrappage models that were implemented into the CAFE Model. IPI, California States et. al., CARB, and other commenters suggested that the NPRM model is over-fit. CARB outlined its argument that the agencies overfit the data in the following passage:

[1232] *See*, e.g. *Ctr. for Biological Diversity v. Nat'l Highway Traffic Safety Admin.*, 538 F.3d 1172, 1203 (9th Cir. 2008),(finding that NHTSA inappropriately assigned no value to reducing carbon emissions when the value for doing so was "certainly not zero.").

[T]he model appears to be significantly overfit and to suffer from multicollinearity. An overfit model means that the model is able to precisely replicate past trends, but only through the use of too many variables. An overfit model fits the data too well, fitting the noise or errors in the data in addition to the underlying relationships between the variables of interest. Because an overfit model also fits the noise and errors of the data, the out-of-sample predictions are unreliable. Comments from Jeremy Michalek and Katie Whitefoot suggest that choice of specification of the scrappage model could result in substantially different predictions, and that the agencies should make only those claims that are robust to reasonable variations in the model specifications.

The agencies agree that it is important that the scrappage model results are robust across those specifications that meet a set of econometric criteria (these criteria are discussed further in Section I.A.1.a)(1)(c)(iii)). However, the agencies acknowledge that the NPRM could have provided further evidence that the specification did not drive the results. In the analysis for the final rule the agencies have presented more than one specification of the price effect as evidence that the specification chosen here does not drive the results of the analysis. Further, claims that the specification of the scrappage response in the NPRM is inconsistent with economic theory are false.

Commented [A322]: **REVISE:** See above comment – the model produced results not supported by economic theory.

This sentence (a) doesn't explain what the commenters said about inconsistencies with economic theory, and (b) doesn't respond. Neither does the following text.

Theoretically, changes in average new prices may have longer-term trends that can be picked up by including lagged terms, and/or be non-linear with age, so that vehicles of different ages have different elasticities of scrappage (relative to changes in average new vehicle prices). Further, sometimes the effect of one independent variable on the dependent variable depends on the magnitude of another independent variable–this is called an interaction effect. Regression analysis can capture these interaction effects by defining a new variable using some combination of independent variables.[1233] It is necessary to retain such interaction terms when doing so.[1234] For example, it is not obvious that the elasticities of scrappage rates to changes in new vehicle prices should be constant for all vehicle ages, or put another way, the older a vehicle is, the higher likelihood the vehicle will be scrapped instead of being retained or resold.

Michalek and Whitefoot, Honda, and other commenters, argued that the fact that some of the interaction terms were not statistically significant was evidence that the response measured is uncertain. CBD in particular claimed that the "scrappage model is poorly constructed, and its results are not statistically significant."

In response to such comments, it is important to note that when interaction terms are included, the significance of the overall effect of a variable should be tested by performing a restricted F-test, which simultaneously tests that all coefficients of the variable of interest are jointly indistinguishable from zero. The insignificance of one term of the interaction does not imply that the effect is indistinguishable from zero.[1235]

Commented [A323]: **REVISE:** The first part of this highlighted section is not true. A t-test is used to examine the significance of a single variable. (Well, IIRC, a restricted F test for 1 variable and a t test for that variable give exactly the same information.) An F-test is used to examine the significance of several variables jointly.

Commenters also noted the lagged terms and age interactions make the new vehicle price effect difficult to interpret. IPI argued that "[t]he inclusion of interaction variables make it very

[1233] Davis, J. B., *Statistics using SAS enterprise guide*. Cary, NC: SAS Institute, pp. 411-415 (2012).
[1234] As explained in more detail in Section [xxx] below, the agencies perform several sensitivity analyses to ensure the model captures the correct impact of interactive effects.
[1235] Davis, J. B., *Statistics using SAS enterprise guide*. Cary, NC: SAS Institute, pp. 411-415 (2012).

difficult to evaluate the results of the regression for an individual variable of interest." Michalek and Whitefoot suggested "using a Monte Carlo analysis to understand the distribution of scrappage outcomes implied by uncertainty of the value of the coefficients in the model regression and reporting 95% confidence intervals."

We agree that the inclusion of lags and age interactions of new vehicle prices can make interpreting the sign and magnitude of the price effect difficult. It also makes it difficult to use the confidence intervals on the coefficients as a way to capture uncertainty, since the interaction variables are jointly estimated. Thus, for the NPRM analysis, we could not independently sample each coefficient from the confidence intervals and perform a Monte Carlo analysis.

While the agencies think that the inclusion of lags and interaction terms is theoretically plausible, in response to commenter and peer reviewer concerns about overfitting and the difficulty of interpreting coefficients, the agencies reconsidered the time series approach. The agencies found that new vehicle prices are integrated to order one and that the dependent variable is stationary (as discussed in Section I.A.1.a)(1)(c)(iii)(a)). It is therefore sufficient to fit the first difference of new vehicle prices within the models. Thus, the agencies have simplified the central model of the response of scrappage rates to changes in new vehicle prices to exclude lags of the effect. The agencies further simplified the central scrappage models to exclude interaction of new vehicle prices and vehicle age; this allows the agencies to take the 95 percent confidence intervals as a low and high range for the magnitude of the price effect for the sensitivity analysis. The agencies also include a sensitivity analysis which includes interaction terms between new vehicle price and vehicle age to allow the elasticity of scrappage to changes in new vehicle price to vary by vehicle age.

Commenters also noted that the model did not perform well for vehicles beyond age 20. The agencies noted in the PRIA that the Polk dataset for older vehicles was limited and likely led to the inability to estimate the scrappage rates for older ages.[1236]

The final rule dataset includes almost 30 percent more data for vehicles fifteen years or older than the NPRM, which improves estimates of the scrappage rate of vehicles aged 20 to 30 (see Table VI-98Table VI-98). The agencies are still unable to capture the scrappage trends for vehicles over 30, as the dataset is still limited for the oldest ages of vehicles, and still rely on the decay function used in the NPRM for vehicles over the age of 30. The limited data explains the inability to predict the scrappage rates for older vehicles. However, including model year fixed effects and including the share of the initial cohort remaining does improve predictions of the final share remaining in the final rule models. These changes are discussed in Section (c)(i)(c).

(b) Reduced Form and Endogenous Prices

California States et. al., CARB, EDF, IPI and academic commenters expressed concerns that the NPRM analysis fit a reduced form of the scrappage model, rather than a structural model. In other words, instead of explicitly modeling new and used vehicle prices in equilibrium under different regulatory alternatives and applying a measurement of the elasticity of scrappage

[1236] Cite 2018 PRIA.

to the resulting *used* vehicle prices, the agencies modeled the elasticity of scrappage from changes to *new* vehicle prices. For example, California States et. al., argued that the model "does not link the new and used vehicle markets as required by economic theory, nor does it attempt to measure used vehicle prices, which form the basis of scrappage theory."

While the agencies recognize that there are certain advantages to a structural model, they disagree that the sales of new and used vehicles must be modeled simultaneously. The agencies do link the new and used car markets by including new vehicle prices as an independent variable in scrappage regression equation. However, it would be inappropriate to include used vehicle prices in this equation due to endogeneity concerns. A change in used vehicle prices may change scrappage rates, but also an exogenous shock to scrappage rates may cause used car prices to vary. Furthermore, the agencies are unaware of a viable structural model for the scrappage effect. The agencies performed an extensive review of economic of literature, both before creating the scrappage model for the proposal and revising it for the final rule, but were unable to find such a model or any insights on how to construct one. The agencies note that commenters did not suggest a structural model that the agencies should use or give any indication of whether such a model exists.

Commented [A324]: **REVISE:** If that's right, then the coefficient on new vehicle price is biased; it includes more than the effect of new vehicle prices. As a result, the scrappage model will not accurately predict the effect of a change in new vehicle price on scrappage.

Commented [A325]: **REVISE:** Isn't the model an attempt to model those exogenous shocks? If it doesn't capture them, then there's potential for omitted variable bias.

In order to understand why such a model is difficult to construct, it is important to understand what a structural model of the sales and scrappage responses would entail. A hypothetical structural model for the new vehicle market can be represented by the following simultaneous demand and supply equations:

Commented [A326]: **REVISE:** The commenters wanted, not separated models for new & used, but rather a jointly estimated model that considered overall demand for vehicle ownership.

$$D_{New} = \beta_0 + \beta_1 * P_{New} + \beta_2 * P_{Used} + \beta_3 * P_{Transit} + \beta_4 * Income + \beta_5 * Households$$

$$S_{New} = \beta_6 + \beta_7 * P_{New} + \beta_8 * Production\ Cost_{New}$$

The demand equation for new vehicles in a given year is determined by the annual price of owning and operating new vehicles, the annual price of owning and operating used vehicles, the annual price of other substitutes, average household income, and the number of households. The supply equation is made up of the average price of new vehicles and the average cost to produce them.

As noted in Section [xxx], reducing required fuel economy stringency reduces the cost of producing new vehicles, and shifts the supply curve to the right. This results in an increase in the quantity supplied of new vehicles.

The structural model for the used vehicle market can be represented by the following simultaneous demand and supply equations:

$$D_{Used} = \gamma_0 + \gamma_1 * P_{Used} + \gamma_2 * P_{New} + \gamma_3 * P_{Transit} + \gamma_4 * Income + \gamma_5 * Households$$

$$S_{Used} = \gamma_6 + \gamma_7 * P_{Used} + \gamma_8 * Maint\ Repair_{Used} + \gamma_9 * Scrap\ Value_{Used}$$

The aggregate demand equation for used vehicles is determined by the price of owning and operating used vehicles, the price of owning and operating new vehicles, the price of other transit substitutes, average income, and the number of households. The supply curve equation

for used vehicles is determined by the price of used vehicles, the cost to repair and maintain them in service, and the opportunity cost of the scrappage value of doing so. Relaxing new vehicle standards reduces new vehicle prices and shifts the demand curve for used vehicles downward, which reduces demand for used vehicles and the equilibrium price and quantity of used vehicles, and increases the annual scrappage rate.

Modeling the structural equations would require that the agencies predict new and used vehicle prices in equilibrium; that prices of new and used vehicles be determined simultaneously from estimates of the supply and demand curves of each market. [Text Forthcoming]. As CARB stated in the following comment, new and used vehicle prices are endogenous—the equilibrium prices of each good are simultaneous:

> Because both scrappage rates and new vehicle prices may influence one another, the Agencies would need to utilize different statistical techniques to credibly identify the impact of new vehicle prices on scrappage rates. For example, the Agencies would need to identify an instrumental variable that impacts new vehicle price but that does not impact the scrappage rate. Models that suffer from endogeneity problems will have biased estimates. In other words, the estimates from these models cannot be used to inform policy, because they do not actually tell us how new vehicle prices impact scrappage.

CARB suggested a way to correct for endogeneity: using an instrumental variable in a two-stage least squares methodology where the instrumental variable is correlated with new vehicle prices, but not scrappage rates. [CITE] The agencies could also model this in two steps. First, they could model the impacts of exogenous changes in new vehicle prices on used prices, and second, they could model the impacts of exogenous changes in used prices on scrappage rates. To do the first would require an instrumental variable which could isolate exogenous shifts to the new vehicle supply curve, and then to use the predicted values to model changes in used vehicle prices of all vehicle ages. Vehicle prices and scrappage rates are jointly determined. Thus, predicting the elasticity of scrappage to own price variation also requires isolating exogenous changes in used vehicle price with an instrumental variable.

There is one literature example that approaches the structural model that some commenters would like the agencies to implement. Jacobsen and van Bentham[1237] developed a structural model that simultaneously solves for prices that clear new and used vehicle supplies, and then applies an elasticity of scrappage measure that corrects for potential endogeneity of used vehicle values and scrappage rates using an instrumental variable methodology. Specifically, they use changes in fuel prices as an instrumental variable; changes in fuel prices shift the demand for different vehicle models, but not the cost of supplying them. This should capture exogenous changes in value, so that an exogenous measure of the scrappage elasticity can be isolated in the second stage of the two-staged least squares method.

[1237] M. Jacobsen and A. van Benthem, "Vehicle Scrappage and Gasoline Policy," *American Economic Review*, Vol. 105, pp. pp. 1312-38 (2015).

While Jacobsen and van Bentham are able to correct for potential endogeneity between used vehicle values and their scrappage rates, their structural model to set new and used vehicle values simultaneously makes some presumptions that the agencies are not comfortable making. First, they calibrate their constant elasticity of substitution (CES) utility function using 1999 data from GM's internal model. This type of model would estimate elasticities of specific vehicle models and require a pricing strategy other than allotting all additional technology costs to the vehicle models to which they are applied. The agencies have avoided a pricing strategy for the reasons cited in Section [xxx]. Second, by relying on GM's internal model, Jacobsen and van Bentham used elasticities calculated using only 1999 data of the GM fleet. The agencies do not expect that elasticities estimated from 20-year old data from a single OEM's portfolio of vehicles would translate to the entirety of the current vehicle fleet.[1238] Finally, Jacobsen and van Bentham represent total vehicle demand of a representative consumer from a composite vehicle. This approach precludes the realistic consideration that a household may prefer two used vehicles over one new vehicle, which is accounted for in the agencies' functional equations.

Jacobsen's and A. van Benthem's model is not a household level choice model, and is not meant to determine fleet size as noted in their comment:

> In summary, while the Jacobsen and van Benthem (2015) paper cannot inform by how much the total vehicle fleet would expand under a CAFE rollback (since we do not estimate by how much it shrinks under CAFE), all the evidence and economic logic points to a larger total vehicle fleet under a rollback, at odds with NHTSA's fleet turnover model.

The agencies agree that the long-term fleet should be smaller in the augural case, as fewer new vehicles flow into the used car market (because of lower sales), but do think it is plausible that in the short term the fleet size *could* increase under augural standards if in some cases consumers substitute two used vehicles for one new one or choose to retain an additional vehicle on the margin because the higher value makes doing so a more reasonable investment (at the annual level). This sort of outcome is not possible with the Jacobsen and van Bentham 2015 model, because the overall demand for vehicles is set by the annual rent prices of a composite vehicle. The updates to the scrappage model for the final rule are consistent with this view, but do show a smaller fleet size under the augural standards relative to the proposal. This is discussed further in Section (c)(iv).

Commented [A327]: **REVISE:** EPA disagrees that this is plausible. To our knowledge, no commenter considered this finding plausible either. For this to be true, the demand curve for used vehicles must slope upward. It's hard to imagine used vehicles being inferior (i.e., higher income reduces demand), much less Giffen goods (income effect dominates substitution effect, and quantity demanded rises with higher price).

Fitting the reduced form equation requires that endogenous variables are excluded from the model to avoid biased coefficients, so that used vehicle prices were omitted by design because used vehicle prices and scrappage rates are endogenous.[1239] Some commenters argue that new vehicle prices and scrappage rates are also endogenous; CARB argued that "the model

[1238] Kleit, Andrew N., 2004. "Impacts of Long-Range Increases in the Corporate Average Fuel Economy (CAFE) Standard." Economic Inquiry 42:279-94.
[1239] Hill, R. C., Griffiths, W. E., & Lim, G. C. Chapter 11: Simultaneous Equation Models. In *Principles of Econometrics* (3rd ed., pp. 303-324). Hoboken, NJ: John Wiley & Sons, Inc. (2008).

tries to rely solely on new vehicle prices to predict scrappage rates without realizing or controlling for the fact that scrappage rates may also affect new vehicle prices."[1240]

[Text Forthcoming].

The agencies chose not to fit a model predicting used vehicle prices directly from new vehicle prices for the proposal because currently-available time-series data on the prices of used vehicles of a given vintage going back to 1975 is limited. EDF cited the lack of available data as the reason not to fit the structural model:

> In the absence of any data or analysis, NHTSA did not describe the extent to which changes in new vehicle prices affect used vehicle prices of varying age, condition, etc.[1241]

The agencies note that acquisition, assembly, and cleaning of a nationally representative database for calendar years 1974 to 2017 on used vehicle prices by vintage from Kelly Blue Book (or a similar source) would take months to years, and would push the final rule beyond the necessary April 2020 lead time requirement to set MY 2022 standards. Kelly Blue Book data is readily searchable for current prices, but without a time series of used vehicle prices the data cannot be used to answer the causal relationship of changes in used vehicle prices over time on vehicle retirement rates. Even assembling a nationally representative sample of used vehicle prices by vintage would be a major undertaking. This is not to suggest that doing so is out of scope for future analyses; the agencies plan to consider further the possibility of conducting additional analysis on the relationship between new and used vehicle prices.

The agencies considered use of the Consumer Expenditure Survey (CEX), which has reported vehicle transaction data annually since 1984.[1242] However, the sample of used vehicle purchase prices aged twenty and older is severely limited. For vehicles purchased between 1996 and 2017, the average number of transaction prices reported for vehicles aged 20 is 58, and for vehicles aged 25 is 18. Any computation of average used vehicle prices from such a small sample would not be reliable, and in fact, would be quite noisy. The agencies do not think that estimates of a structural model based on such limited sampling would improve the prediction of the scrappage effects over use of the reduced form equation.

Commented [A328]: REVISE: Those are also likely to be a very small part of the fleet. Why is availability of data on those driving the analysis?

EDF argued that modeling the impact of changes in new vehicle prices directly on used vehicle scrappage may not capture the fact that changes in used vehicle prices impact vintages differently. Further, they argue that if new and used vehicle prices change by the same proportion, the effect will have a very small impact on the prices of the oldest used vehicles. They argue that these small changes are not enough to change the scrappage decisions:

> Given that vehicles can sell for as little as a couple of hundred dollars and new vehicle prices average over $30,000, used vehicle prices can be as little as 1% of that of a new vehicle. Given that the largest increase in new vehicle prices projected by NHTSA in the

[1240] [Text Forthcoming].
[1241] [Text Forthcoming]
[1242] [Cite: https://www.bls.gov/opub/hom/cex/history.htm].

NPRM is less than $3000, and assuming that its effect on used vehicle prices is likely to be roughly proportional to current relative prices, this might mean that the value of a very old vehicle or one in poor condition might only increase by $30 (decline by $30 under the proposal). It is difficult to see how such a change in value would have a measurable impact on scrappage. Of course, the impact of an increase in new vehicle prices on used vehicle prices might be more or less than proportional to their current relative values. However, NHTSA has done nothing to show which might be the case. The probability of any realistic change in used vehicle prices to induce the scrappage of used vehicles is still a complete mystery.

However, the age interaction on the new vehicle price effect allows that the elasticity of scrappage to changes in new vehicle prices may not be constant for all ages. Allowing the scrappage elasticity to new vehicle prices to vary by age incorporates the fact that the elasticity of scrappage of used vehicles and the cross-price elasticity of used vehicle demand to new vehicle prices may not be constant with age. At some point, the thirty-dollar increase EDF cited could be the difference in keeping a marginally used vehicle on the road; it would be a 10 percent increase in the price of a used vehicle, and may cover State registration fees on a marginally scrapped vehicle.

(c) Time Series

The scrappage model utilizes panel data. Panel data observes multiple individuals or cohorts over time. The data employed by the scrappage model observes the scrappage rates of individual model year cohorts between successive calendar years. The model allows for the isolation of trends over time and across individuals.[1243] Since the scrappage model uses aggregate model year cohorts to estimate scrappage rates by age and time-dependent variables (new vehicle prices, fuel prices, GDP growth rate, etc.) panel data is necessary to estimate the model. A major challenge to using panel data is that the data structure requires consideration of potential violations of econometric assumptions necessary for consistent and unbiased estimates of coefficients both across the cross-section and along the time dimension. The cross-section of the scrappage data introduces potential heterogeneity bias—where model year cohorts may have cohort-specific scrappage patterns.[1244] Another way to put this is that each model year may have its own inherent durability. The NPRM captured this potential bias by including model year as a continuous variable, but the model amended for the final rule includes the more traditional individual fixed effects. This is discussed in Section 0. The time dimension of a panel introduces a set of potential econometric concerns present in time series analysis. The agencies considered potential autocorrelation in the error structures and included lags of the dependent and specific independent variables to correct for it; this is not an uncommon practice in dynamic panel models.[1245] Some commenters argued that time series approaches were not appropriate in the scrappage model at all. CARB stated the following:

Commented [A329]: **REVISE:** How are the effects of MY projected for future MYs?

[1243] Cambridge University Press. (1989). *Analysis of Panel Data*. New York, NY.
[1244] Cambridge University Press. (1989). *Analysis of Panel Data*. New York, NY.
[1245] Bun, M. J. G., & Sarafidis, V. (2015). Dynamic Panel Data Models. In *The Oxford Handbook of Panel Data* (pp. 76–110). New York, NY: Oxford University Press.

Time-series analysis for modeling scrappage is also inappropriate for the same reasons as it was for the new vehicle sales model—particularly because time-series analysis does not capture structural changes, which the scrappage model seeks to illustrate.

The agencies disagree with CARB's assessment. The potential scrappage effect can only be measured with a time series dimension; the agencies are interested in how changes in new vehicle prices *over time* impact the retirement rate of the on-road fleet *over time*. In order to isolate this effect, the agencies need multi-period data on the scrappage rates of used vehicles and prices of new vehicles.

The literature on vehicle scrappage rates utilizes panel data, but most research has ignored potential autocorrelation issues caused by the structural properties of independent variables that vary along the time dimension. With the NPRM analysis, the agencies found evidence of auto-correlated errors, which were corrected by including three lagged terms of the dependent variable.[1246] While in a pure time series analysis, this can be an appropriate methodology to account for autocorrelation in the error structure; estimates of the coefficients of the lagged dependent variable are biased downwards when applied in fixed or random effects panel models. The reason for this is that the constant individual specific terms are correlated with the lagged dependent variable (by definition, since the individual specific terms are constant for all time periods, including the previous period), creating a bias in the estimate of the coefficient on the lagged dependent variable, and potentially other measures.[1247] The eponymous bias was first discussed in a paper written by Nickell in 1982.[1248] There is an increasing body of work developing estimators built specifically for dynamic panel data (DPD), or panel data where there is an autoregressive component to the data-generating process. In other words, the previous value of the dependent variable impacts the current value.

Further research into this literature (discussed above), comments on the NPRM, and peer review comments prompted the agencies to reconsider the approach developed for the NPRM. The NPRM analysis did not use fixed effects for specific model years, but instead imposed a parametric logarithmic relationship of successive model years. This parametric model year term will still result in biased estimates of the lagged dependent variable because it also does not vary over time for the same model year, and is therefore correlated with the autoregressive term. Since the autoregressive term carries through effects from the previous period (the new vehicle price effect), this will also bias the predicted Gruenspecht effect in the NPRM model. Updates to the model used for the final rule correct this issue by more deliberately considering the time series properties of both the dependent and independent variables.

[1246] FR, Vol 83, No. 165, August 24, 2018, p.43097.
[1247] Allison, P., Don't Put Lagged Dependent Variables in Mixed Models,, (2015, June 2). Retrieved June 1, 2019, from https://statisticalhorizons.com/lagged-dependent-variables.
[1248] Nickell, Stephen. "Biases in Dynamic Models with Fixed Effects." *Econometrica*, vol. 49, no. 6, 1981, pp. 1417–1426. *JSTOR*, www.jstor.org/stable/1911408.

In reconsidering the appropriate way to address the time series properties of the scrappage model, the agencies first consider the stationarity of dependent and independent variables. This was suggested in James Sallee's peer review:

> In contrast to the new vehicle sales regression reported in the PRIA's section 8.6, the discussion of the scrappage regressions does not include any discussion of the time series properties of the estimators. It is important to test for non-stationarity, for example.[1249]

Importantly, we find that the instantaneous scrappage rate is stationary, so that there is no longer term information in the scrappage rates to recover with an autoregressive term. This means that a DPD model is not necessary to correct for potential autocorrelation in the model. This also implies that the autocorrelation in the errors is a result of non-stationarity in some or all of the regressors, and not the independent variable. The solution to this problem is to identify the order of integration of each regressor and difference until each is non-stationary. Table VI-100Table VI-100 in Section (c)(iii)(a) shows the order of integration of variables considered in the scrappage modelling.

Commented [A330]: CHANGE AS SHOWN: Independent variables are regressors. . . .

(ii) Modeling Fuel Economy

(a) Counterintuitive Signs

In the NPRM analysis, the agencies controlled for the changes in the relative fuel economy of new and used vehicles by including the cost per mile of travel in the current period and the previous period for both new vehicles and the model year cohort whose scrappage is being predicted. This allowed fuel prices to alter the scrappage rates of existing vehicles, meaning model year cohorts with lower-than-average fuel economies were impacted by increases to fuel prices to a greater extent than cohorts with higher-than-average average fuel economies. It also allowed increases in the fuel economy of new vehicles to impact the scrappage rates of existing vehicles; the idea is that when new vehicles have a higher average fuel economy, holding price constant, the demand for new vehicles should increase relative to used vehicles, and scrappage rates should increase. While this was a plausible way of controlling for changes in the relative fuel cost per mile of usage of new and used vehicles, the agencies noted in the NPRM that some of the signs on new vehicle cost per mile were counterintuitive, so that increases in the average new vehicle fuel economy of certain body styles actually increased the scrappage rates of existing vehicles.

IPI, CARB, CBD, Natural Resources Defense Council (NRDC), and other commenters argued that these results were driven more by modeling decisions than by actual relationships within the data. NRDC suggested that the conclusions from the NPRM model should be treated with suspicion until validated by further research:

> [A]n increase in fuel price for a given level of fuel economy results in longer vehicle retention even though operational costs per mile increase. While it is not possible to

[1249] *CAFE Model Peer Review* (Report No. DOT HS 812 590). Washington, D.C. – National Highway Traffic Safety Administration, B-64.

rationalize this response without significant additional research, it is indicative of the fact that the algorithm response functions may not be properly defined.

The agencies agree that the results were counter-intuitive—having identified this issue in the NPRM and specifically seeking comment on the matter—and considered multiple alternative methods of capturing the fuel economy improvements of new vehicles within the scrappage model in response to comments. Among the changes considered were alternate forms of modeling the form of new vehicle fuel economy, as suggested by IPI:

> A paper by Shanjun Li et al., provides a useful example of how the agencies could include fuel efficiency in their regression without raising the econometric concerns that may be leading to their nonsensical results. Li et al. include fuel price and vehicle fuel efficiency (gallons per mile) of used vehicles as well as a variable that captures the interaction of fuel efficiency of used vehicles and fuel price in their regression as explanatory variables. [Footnote 407: Li et al. (2009), at 127.] Unlike the agencies' model, the regression analysis used in the Li et al. paper found results that are consistent with economic theory: a decrease in overall demand for vehicles and an increase in demand for more fuel-efficient cars.

The NPRM included changes in new vehicle cost-per-mile, but did not include separate variables for fuel prices or fuel economy. This could potentially have conflated changes in the cost-per-mile of new vehicles from changes in fuel prices and changes in new vehicle fuel economy. The agencies considered including changes in fuel prices and new vehicle fuel economy as separate measures, as suggested in IPI's comment above, but opted for a different method of addressing the concern of how to include changes to new vehicle fuel economy in the scrappage model. However, specifications considering this approach are shown in Section I.A.1.a)(1)(c)(iii)(d).

(b) New Vehicle Prices Net of Fuel Savings

UCS, CBD, NRDF, EDF, and other commenters expressed concern that quality adjustments were not included in the price series used to fit the NPRM model. In particular, commenters suggested that the valuation of fuel savings at the time of purchase should be deducted from the new vehicle price increases. For example, CBD argued:

> . . . [T]he agencies rely heavily on work by Howard Gruenspecht regarding the scrappage effect, and the NPRM acknowledges that Gruenspecht considered the effect of an increase in price "net of the portion of reduced fuel savings valued by consumers." Yet consumer valuation of fuel savings is excluded from the scrappage model, as well.

The scrappage model cannot include both independent variables on the fuel economy and cost-per-mile of new vehicles, and adjust the new vehicle prices by the value of fuel savings considered at the time of purchase, which would account for the improvement of the fuel economy of new vehicles twice. Thus, the agencies must choose between these methods to capture the value improvement of new vehicles when their fuel economy increases. The agencies show both methods in Section I.A.1.a)(1)(c)(iii)(d). However, additional comments

give reason to prefer a methodology that does not model the fuel economy or cost per mile of new model year cohorts directly, but instead adjusts the new vehicle price series by the amount of fuel savings valued at the time of purchase.

IPI expressed concern that the cost-per-mile measure was included in the scrappage model, but not in the sales model:

> [T]he CPM results in the scrappage model are inconsistent with the agencies' sale model. In the sales module, the agencies have chosen to ignore consumer demand for fuel economy and significantly boosted the price impact of the baseline standards as a result. But in the scrappage model, the agencies have incongruously allowed consumer valuation of fuel economy to drive a significant portion of the estimated fatalities.

The agencies note that the fuel economy of new vehicles was not included in the sales model because the signs were statistically insignificant when it was included, and the fit of the overall model was not improved. It was not excluded because the agencies do not think that new vehicle fuel economy does not affect their sales. One way to consider the value of increased fuel economy in both the sales and the scrappage model (in the same way) is to adjust the price of new vehicles by the amount of fuel savings consumers value at the time of purchase in both models. This is also consistent with how the CAFE model applies technology in the absence of CAFE standards, or when a manufacturer is already in compliance with existing standards; discussed in Section [xxx]. In respoose to comments about the counterintuitive signs of the change in new vehicle cost per mile for some body styles, and about the disconnect in how the fuel economy of new vehicles is modelled in the sales and scrappage models, the agencies have adjusted the new vehicle price series in both models by the amount of fuel savings consumers are assumed to value at the time of purchase (30 months of fuel savings). As noted in Section I.A.1.a)(1)(b)(ii)(a), alternatives to this solution are presented in Section I.A.1.a)(1)(c)(iii)(d). We also discuss consideration of other quality improvements over successive model years in Section I.A.1.a)(1)(b)(iii)(d).

(iii) Consideration of Other Additional Variables

Some commenters expressed concern that the scrappage model implemented in the NPRM analysis omitted several theoretically important variables in predicting the scrappage rates of the existing vehicle fleet. To understand these comments more fully it is useful to recall that existing vehicle owners can be private households/individuals, businesses, or dealerships. They supply the used vehicle (in the sense of making it available for use) to the market either by reselling them, or continuing to own the vehicle for their own use. Theoretically an existing owner will supply a used vehicle for additional use if the value of the vehicle (net of the opportunity cost of its value as scrap metal and used parts) exceeds the cost of maintenance, repair, insurance, and registration fees for the vehicle. If a seller does not perform necessary repair or maintenance services on the vehicle prior to sale, the value of the vehicle should be offset by the cost of those services. Accordingly, the scrappage threshold for a vehicle should remain the same regardless of whether the seller or buyer pays for any necessary maintenance or repair services on the vehicle.

Under this framework, commenters have argued that the agencies should include maintenance and repair costs, the value of the used vehicle when scrapped, and other costs to purchase the vehicle, all of which were excluded in the NPRM version of the scrappage models. IPI stated the following:

> The agencies should include the variables that Gruenspecht and others have traditionally included in their scrappage analysis, including price of vehicles indexed by maintenance and repair costs, the price of scrap metal, and interest rates.

The agencies agree that these variables are relevant to determining the scrappage rates of existing vehicles, but have concerns that the level of aggregation of available series related to each of these factors may obscure the ability of a statistical model to capture their impact on vehicle scrappage rates. Below, we discuss commenter concerns about the omission of maintenance and repair costs, scrap steel prices, and interest rates, in turn. We then outline the agencies' further consideration of each factor in this final rule analysis, and why each chose whether to consider each factor in the analysis for the final rule. Empirical results of models considering these factors are shown in Sections I.A.1.a)(1)(c)(iii)(e) and I.A.1.a)(1)(c)(iii)(f); the decision to exclude them from the primary analysis is further explained in these sections.

(a) Maintenance and Repair Costs

EDF, IPI, California States et. Al., CARB, CBD, and other commenters suggest that the omission of maintenance and repair costs by the agencies was not justified, and that the measure should be included in future models. CARB claimed that:

> parameters for repair costs and used vehicle prices towards the end of life should likely be included in a scrappage model. However, neither of these variables appear in the Agencies' model.

The agencies agree that the theoretically ideal model of scrappage would include maintenance and repair costs. For this reason, the agencies explored several methods for explicitly incorporating maintenance and repair costs. Section I.A.1.a)(1)(c)(iii)(f) reports model results both with and without a maintenance and repair variable. Since the variable is integrated of order one, (see Table VI-98Table VI-98), the models including it take the first difference; in this form, increases in maintenance and repair costs result in an increase in the scrappage rate of existing vehicles, as expected. The sign is also statistically significant. While the agencies would prefer a maintenance and repair price series that varies by calendar year and vintage, such a series is not currently available. We hope to continue to improve this variable in future work on the scrappage model, but respond to comments by including the first difference of the maintenance and repair series in some of the models considered for the model used for the final rule.

Commenters were apparently confused about the agencies' discussion of the impact of fuel economy standards on durability. The agencies discussed a finding from the Greenspan and Cohen (1996) paper that suggested that higher EPA emission standards actually decreased the durability of certain model years. The discussion from the PRIA follows:

> In addition to allowing new vehicle prices to affect cyclical vehicle scrappage à la the Gruenspecht effect, Greenspan & Cohen also note that engineering scrappage seems to increase where EPA emission standards also increase; as more costs goes towards compliance technologies, it becomes more expensive to maintain and repair more complicated parts, and scrappage increases. In this way, Greenspan and Cohen identify two ways that fuel economy standards could affect vehicle scrappage - 1) through increasing new vehicle prices, thereby increasing used vehicle prices, and finally, reducing on-road vehicle scrappage, and 2) by shifting resources towards fuel-saving technologies—potentially reducing the durability of new vehicles by making them more complex.[1250]

EDF and IPI misinterpret the agencies' discussion of findings from Greenspan and Cohen's work to imply that the fuel efficiency variable is meant to control for changes in maintenance and repair costs. The following quote from IPI exemplifies their confusion:

> In addition, the agencies have explicitly excluded several theoretically important explanatory variables (e.g., the cost of maintenance and repair), which are potentially correlated with fuel efficiency. [Footnote 405: Id. at 1000 (indirectly making this point with respect to fuel efficiency and maintenance and repair costs when emphasizing that 'Greenspan & Cohen also note that engineering scrappage seems to increase where EPA emission standards also increase; as more costs goes towards compliance technologies, it becomes more expensive to maintain and repair more complicated parts, and scrappage increases'). In other words, maintenance and repair costs are correlated with respect to fuel efficiency and scrappage rates.]

The agencies did not mean to imply that including some measure of the fuel economy of a model year cohort (cost per mile, in the NPRM model) would control for variation in maintenance and repair costs over time. The discussion of Greenspan and Cohen's results was intended only to demonstrate that durability and standards that increase technological complexity may be correlated, so that durability increases may not be independent of CAFE/CO_2 standards.

Maintenance and repair costs for a given model year cohort likely are correlated with the fuel saving technologies applied to that cohort, but there is also a dimension of maintenance and repair costs that are correlated with other macroeconomic factors (i.e., wages, materials, etc.). Controlling for fuel economy would not capture calendar-year-specific changes to maintenance and repair costs that are caused by factors other than fuel economy. It also does not seem likely that variation in maintenance and repair costs from different fuel savings technology would be linearly related to fuel consumption, so that even model year variation in maintenance and repair costs could not be captured by including some measure of fuel economy or fuel consumption. As noted above, the agencies agree that maintenance and repair prices exist in the theoretically ideal scrappage model, and consider the variable in some of the models presented in Section I.A.1.a)(1)(c)(iii)(f).

[1250] PRIA at 1000.

(b) Scrap Values

In the NPRM model, the agencies considered inclusion of the BLS scrap steel CPI series. We gave the following reasons for excluding the measure in the final NPRM models on page 1012 of the PRIA:

> As noted by Parks (1977), the value of a scrapped vehicle can be derived either from the value of recoverable scrap metal or from the value of sellable used parts. There are several issues with using the BLS scrap steel CPI. First, as in Park's work, the coefficient on scrap steel is statistically insignificant—model results including the CPI of scrap steel are not shown, as there were other theoretical problems with the measure. The material composition and mass of vehicles has changed over time so that the absolute amount of recoverable scrap steel is not constant over the series. The average weight of recoverable steel by vintage would have to be known, and this measure would still be missing any other recoverable metals and other materials. Further, projecting the future value of the recoverable scrap metal would involve computing the amount of recoverable steel under all scenarios of fuel economy standards, where mass and material composition are assumed to vary across all alternatives. This value is not calculated explicitly in the current model, which is another reason some estimate of the value of recoverable metal is not included in the preferred model specification.

The concerns the agencies raised in the NPRM continue to be present for the model used for the final rule. The BLS scrap steel CPI will not have the same effect on the opportunity cost (the scrap value) of keeping an existing vehicle on the road as opposed to scrapping it for successive model year cohorts. The average weight of vehicles has changed over successive model years, as has the average steel composition.

Even considering the limitation of using the BLS scrap steel price series, commenters expressed concern about the exclusion of a variable to capture changes in the value of a vehicle as scrapped metal and/or used vehicle parts. As noted in Section I.A.1.a)(1)(b)(iii)(a), IPI suggested that "the price of scrap metal" should be included, while CARB suggested the model include "used vehicle prices towards the end of life." The agencies made several further attempts to capture this component of vehicle scrappage, and address commenters' concerns, in the scrappage models used in the final rule. We continue to consider models which include the BLS iron and scrap steel CPI series; results of these considerations are shown in Section I.A.1.a)(1)(c)(iii)(f).

(c) Interest Rates

IPI and EDF expressed concerns that changes in the real interest rates of vehicle loans had not been included in the final NPRM scrappage model. EDF commented the following:

> NHTSA's model also does not include interest rates or the cost of financing a vehicle, another variable which NHTSA acknowledges affects scrappage. NHTSA itself states that "[a]s the real interest rate increases so does the cost of borrowing and the opportunity cost of not investing. For this reason, it is expected that as real interest rates increase that

> vehicle scrappage should decline. Consumers delay purchasing new vehicles because the cost of financing increases. Conversely, as real interest rates decrease, vehicle scrappage should increase . . . . Yet, NHTSA chooses not to include interest rates in its model since inclusion of interest rates yields results that are opposite to what is expected—"as real interest rates increase, so does the scrappage rate" in NHTSA's model. As discussed above, this is yet another indication that the model is flawed and cannot be relied upon.

The agencies considered real interest rates in the NPRM analysis. Increasing the cost of purchasing a vehicle should increase the incentive for households to hold onto existing vehicles (as opposed to purchasing one) and scrappage rates should decline. We excluded real interest rates from the final NPRM model for the reasons stated on page 1028 of the PRIA:

> Table 8-14, Table 8-15, and Table 8-16 include interest rates and maintenance and repair CPI for cars, vans/SUVs, and pickups, respectively. For cars, as shown in Table 8-8, real interest rate is of the opposite sign than expected; as real interest rates increase, so does the scrappage rate—this model is also a worse fit by measures of AIC and BIC relative to the preferred model.

In response to commenters' concerns, the agencies continue to consider interest rates in the model used for the final rule, as shown in Section I.A.1.a)(1)(c)(iii)(e). However, interest rates only affect scrappage rates where a household might be unable to finance the purchase of a new or used vehicle and instead decides to maintain an existing vehicle that would have otherwise been scrapped. The most likely substitute for a marginal scrapped vehicle would not be a vehicle that could be financed. Accordingly, the relationship between interest rates and scrappage rates may be weaker than that between new vehicle prices and scrappage rates. The most likely substitutes for new vehicles are vehicles just off lease, and the resulting increase in residual values will affect slightly older vehicles. Eventually, the price of the most likely substitutes for marginally scrapped vehicles will also increase, so that scrappage rates will also be affected.

(d) Other Vehicle Quality Adjustments

CARB and other commenters expressed concerns that the NADA series used by the agencies in development of the NPRM scrappage model did not make quality adjustments. CARB made the following specific comment:

> By only including new vehicle prices and no other controls for vehicle quality, the Agencies' scrappage model omits variables that are important predictors of scrappage rates and of vehicle prices. Prior work that has relied on new vehicle prices to estimate scrappage rates have also included some aspects of quality improvements, meaning considering that the vehicle is improving in some way. For example, Greenspan and Cohen (1996) include both the Bureau of Labor Statistics (BLS) new vehicle price index and the BLS cost of repair index.

The NADA average new vehicle transaction price does not control for other average characteristics that may change over successive model years. The agencies considered

controlling for average body style and model year characteristics in the scrappage model as an alternative to including fixed effects in the model. The considered characteristics included: horsepower to weight, zero to sixty acceleration time, and average curb weight. However, performing the *pFtest* implementation of an F-test of goodness-of-fit, from the "plm" R package, suggested that fixed effects are necessary to control for heterogeneity across model years.[1251] For this reason, average characteristics that are constant over calendar years for a given model year cohort cannot be included in the model. We do present specifications that include the ratio of new to used vehicle performance (since this has calendar year level variation and can be included with model year fixed effects) in Section I.A.1.a)(1)(c)(iii)(f).

Commented [A331]: REVISE: If fixed effects for MYs are included, how are they projected for future MYs?

(iv) Integration of Sales and/or VMT, Total Fleet Size, and Total VMT

Some commenters believe the ideal model of how CAFE/CO_2 standards affect sales, scrappage, and usage would be a joint household choice model. RFF makes the following comment:

> The agencies can fix those problems by making two changes. First, they can jointly model VMT and vehicle holdings (i.e., scrappage and new-vehicle purchases). The literature provides many examples of such modeling for guidance (see citations above). Jointly modeling these choices will make the analysis internally consistent and will account for the fact that households do not make scrappage and vehicle use decisions in isolation. If the model predicts that weaker standards cause more scrappage, it will simultaneously estimate any increase in VMT for the remaining vehicles.

The advantage of such a model is that sales, scrappage, and usage would be jointly determined so that the impacts on scrappage is conditional on how increased new vehicle prices affect sales and vehicle prices, and usage is dependent on both effects. The agencies agree that this type of model would better capture the joint nature of the choices of which vehicles to buy, which to sell or scrap, and how much to use each than modelling each effect separately. However, the agencies are not aware of any national dataset that would allow sales, scrappage and usage to be jointly predicted, nor are they confident of such a model's ability to predict better than carrying current market shares forward.

The papers cited in the RFF comment, Linn and X. Dou, 2018;[1252] Berry, Levinsohn, and Pakes, 1995;[1253] and Jacobsen and van Bentham, 2015,[1254] either use the CEX or the NADA transaction price series merged with the Polk registration counts. The CEX is a relatively small sample of households (about 160,000), their vehicle holdings, vehicle purchases, and usage.

[1251] Croissant, Y., Millo, G., & Tappe, K. (2019, September 7). Package 'plm.' Retrieved from https://cran.r-project.org/web/packages/plm/plm.pdf.

[1252] J. Linn and X. Dou, "How Do US Passenger Vehicle Fuel Economy Standards Affect Purchases of New and Used Vehicles?" (Washington, DC: Resources for the Future, 2018);).

[1253] Berry, S., J. Levinsohn, and A. Pakes, "Differentiated Product Demand Systems from a Combination of Micro and Macro Data: The New Car Market," *Journal of Political Economy* 112(1) (2004): 68–105.

[1254] M. Jacobsen and A. van Benthem, "Vehicle Scrappage and Gasoline Policy," *American Economic Review* 105 (2015): 1312-38.

However, it does not report retirement rates, but only when a vehicle exits a household's fleet (most often it is sold or traded in). Thus, at best, the CEX could be used to build a household consumer vehicle holdings and usage model, but the vehicles that are scrapped would be implied; scrappage would not be modeled directly, nor would it be attached to the number of miles on a vehicle. The NADA and Polk datasets used by Jacobsen and van Bentham links vehicles prices and scrappage rates, but does not track individual household decisions. The Jacobsen and van Bentham paper relies instead on a model of the new and used vehicle market which takes cross-price elasticities as an assumption derived from the outputs of a 1997 GM consumer choice model.[1254, 1255] The agencies will continue investigating whether a consumer/household choice model can serve as an alternative to aggregate estimates of sales and scrappage, but are skeptical about the ability of such models to predict future model shares accurately.

As was the case with the 2012 final rule and the 2016 TAR, the agencies again note there is no credible consumer choice model which can be implemented in the CAFE model. Literature comparing the performance of consumer choice models to holding manufacturers constant suggest that the latter predicts future market shares better than the former. NCAT raises this point in their comment below:

> Academic and other researchers have developed a number of vehicle demand (consumer choice) models for the new and/or used vehicle markets to look at effects on sales and fleet mix. Rarely has there been any effort to validate these models, either for consistency across models, or for ability to predict out of sample. Recent academic research, as well as work by EPA, has found that these models commonly perform worse, especially in the short run, than simply holding market shares constant.

For these reasons, the agencies have not used a consumer choice model to capture the sales and/or scrappage impacts, but have built reduced form equations from aggregate data instead.

NCAT and CBD also refer to EPA attempts to develop a consumer choice model in conjunction with Oak Ridge National Labs, and note that the agencies did not use this model for the NPRM analysis. This specific choice model, as referenced in the excerpted NCAT comment above, has not predicted future market shares as well as projecting current shares forward. For this reason the model was not deemed fit to include in the policy analysis. NHTSA also worked to develop a consumer choice model, but when implemented, the model predicted that some OEM's would have unrealistic declines in total sales. The limitations of the consumer choice models the agencies have considered is overlooked in the following comments from CBD:

> The sales model the agencies use is not the consumer-choice model that EPA has been developing and refining for almost a decade. Rather, both it and the scrappage model appear to have been developed by NHTSA in just the last two years. Neither model has been peer-reviewed, nor even released publicly until the publication of this NPRM.

Commented [A332]: REVISE: The point of the comment is that the models for sales & scrappage in the NPRM had not been peer reviewed. This response doesn't address the comment.

[1255] Kleit, Andrew N., 2004. "Impacts of Long-Range Increases in the Corporate Average Fuel Economy (CAFE) Standard." Economic Inquiry 42:279-94.

The agencies did not use the consumer choice models either agency developed because the predictions are not reliable—which has disappointed not only the commenters mentioned above, but the agencies and researchers who have spent significant resources attempting to develop models for these purposes. Instead, the agencies have modelled the effects from reduced form equations from aggregate data.

(a) Integration with Sales Model

The NPRM models did not include any direct linkage between the sales, scrappage, and usage functions, as noted by the agencies. Here, the agencies consider comments from stakeholders about the lack of integration of the scrappage model with sales (and the effect on total fleet size), and the lack of integration with the vehicle usage schedules (and the effects on total VMT).

NCAT, EDF, CBD, CARB, and other commenters argued that the sales and scrappage models should be directly linked, and that their independence predicts the higher fleet size and total VMT under the augural standards. CBD makes the following statement:

> The agencies now, irrationally, decouple those two effects, such that the number of new vehicles sold (or left unsold) has no effect on the number of vehicles scrapped. Relying on the deeply flawed scrappage model, the agencies have predicted a massive ballooning of fleet size under the existing standards that leads, automatically under their model, to a massive increase in VMT.

The agencies note that the structural model presented in Section I.A.1.a)(1)(b)(i)(b) demonstrates that both the equilibrium quantity and the price of new vehicles sold are changed when the production cost of new vehicles changes under different regulatory alternatives. Specifically, under relaxed standards, the equilibrium price is lower and equilibrium sales are higher than the counterfactual augural standards. Controlling for other variables that might shift the new vehicle supply or demand curves, either new vehicle prices or sales could enter the used vehicle demand equation (as in the structural model, there is a functional relationship between the two, again, controlling for factors that shift the supply and demand curves for new vehicles). Thus, the agencies could use either new vehicle sales or prices to control for changes in the new vehicle equilibrium solution in the scrappage equation. It is important to control for factors that affect the demand for vehicles overall (business cycle conditions, etc.). The agencies present the preferred models using either new vehicle prices or new vehicles sales in Section I.A.1.a)(1)(c)(iii)(d). Since there should be a collinearity between the two, it would be inappropriate to include both variables simultaneously.

Commented [A333]: REVISE: This paragraph is not responsive to the comment, which is about the fleet size increasing with higher prices of new & used vehicles under the augural standards in the NPRM.

(b) Total Fleet Size

NCAT, EDF, CBD, CARB, UCS, IPI, California et. al., academic commenters, and other stakeholders argue that the fleet size should not change much with new vehicle prices. Some commenters go further to argue that higher vehicle prices under the augural standards should result in a *smaller* fleet size in the augural case relative to the proposal. The agencies agree that

the long-term impact of higher new vehicle prices should be a slight reduction in fleet size, but do not agree that the short-term impacts of the standards on fleet size are obvious.

Many examples from the literature make assumptions that ensure that the fleet size under different regulatory alternatives remain constant. UCS cites this assumption in the original Gruenspecht works (their emphasis):

> Though the agencies cite the Gruenspecht effect for its basis for the scrappage model, they ignore a central constraint of Gruenspecht's work– namely, his assumption that FLEET SIZE AND TOTAL VMT ARE INSENSITIVE TO PRICE.

Other works ensure the same conclusion with different assumptions. Within the Jacobsen and van Bentham, 2015 and Goulder et. al., 2012 framework, a household first chooses the number of vehicles to own based on the average price of all vehicles subject to a budget constraint. After choosing the number of vehicles to hold, the household chooses the specific type and age of vehicles to hold. However, for some households the choice of how many and which vehicles to hold is not disjoint, so that a household may choose to hold two used vehicles as a second choice to one new vehicle. When new vehicle prices increase, under the same budget constraint, they may choose to hold two vehicles instead of one. If enough households make this choice, the fleet size could slightly increase.

Commented [A334]: REVISE: Evidence? This appears to be an example of a Giffen good – one where the demand curve slopes upward. This seems highly unlikely for the vehicle market. See comment on p. 552.

IPI gives a literature example of a model that does not ensure this outcome with initial assumptions. This model directly predicted fleet size, and not sales and scrappage. The fleet size in the CAFE model is the result of the sales and scrappage models, and not the result of a single of the models. Small and Van Dender, 2007 finds that higher new vehicle prices are associated with lower total vehicle stock, as IPI states in the quote below:[1256]

> In their 2007 study estimating the rebound effect caused by changes in fuel efficiency, Kenneth Small and Kurt Van Dender derived estimates of the relationship between vehicle price and fleet size. By simultaneously estimating a system of equations for VMT per capita, fleet size, and fuel efficiency for the United States from 1966 to 2001, Small and Van Dender also found that an increase in new vehicle price has a negative, statistically significant effect on total vehicle stock.

However, it is worth noting that Hymel, Small, and Van Dender in 2010 published a study finding a statistically insignificant result of the opposite sign.[1257] The general framework of the two papers are very similar, so that the updated results show that the fleet size impact is ambiguous.

Toyota and the Automobile Alliance mentioned that NERA built sales and scrappage models, and requested that the agencies "review the NERA econometric study's methodologies for adoption or to refine their own models." The agencies considered the NERA scrappage model, but note that the model merges the data for all vehicle types, so that the scrappage

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1256

1257 Hymel, Kent M. & Small, Kenneth A. & Dender, Kurt Van, 2010. "Induced demand and rebound effects in road transport," Transportation Research Part B: Methodological, Elsevier, vol. 44(10), pages 1220-1241.

relationship by age for pickups is adjusted by the same constant for all ages. However, the agencies note that each body style has a unique functional form with age (as evidenced in Section 0), so that it does not seem appropriate to merge them. Further, it does not seem likely that the elasticity of scrappage is the same for all vehicle types.

While the agencies think there are reasons not to adopt the NERA scrappage model as is, this suggested general approach does support simplifying the model as further suggested in Section I.A.1.a)(1)(b)(i). Also, this research supports the notion that the relative fleet size of the proposed and augural standards is not a given. NERA's comments about their model provided:

> The separate changes in new vehicle sales and changes in scrappage rates would lead to differences in the overall fleet size for the CAFE standard alternatives. The net effects of these two changes did not have a substantial effect on the overall fleet population under any of the three CAFE alternatives (never more than 0.25% change in fleet size compared to the augural standards).

The NERA model shows the same directional fleet impacts as the NPRM sales and scrappage model. This lends some further support to the notion that the fleet impacts are not as certain as some commenters suggest.

Another empirical model predicts a larger total fleet size under the augural standards than under the proposed standards. Comments by David Bunch offer an extended comparison of the sales, fleet size, and retirement rate results of the Department of Energy's National Energy Modeling System (NEMS) model under the proposed and augural standards. NEMS predicts fleet size from input assumptions about the size of the on-road fleet, endogenous new vehicle sales estimates, and exogenous assumptions about scrappage.[1258] However, in his comments Bunch said:

> Scrappage is an implied behavior determined by projecting total fleet size and new vehicle sales. Through this mechanism, all else equal, an increase in new vehicle sales would yield an increase in scrappage.

NEMS does not project total fleet size endogenously in their model as Bunch assumes. Nor is scrappage an implied behavior determined by fleet size and new sales projections. Instead, total fleet size is implied from an endogenous sales model, and constant age- and body-style-specific scrappage rates. The difference between the CAFE Model and NEMS is that the CAFE model has both endogenous new vehicles sales *and* scrappage rates—scrappage rates are not assumed to be constant for all regulatory alternatives. Fleet size is the implied variable in *both* models.

Bunch finds that the NEMS model also predicts a larger fleet size under the augural standards than the proposed standards. Specifically, he finds the following:

> The differences are initially about 100K, increasing linearly from 2031 from 200K to 1.8M in 2050. Because even the Existing standards remain at the same level after 2025,

[1258] From page 109 of 2016 NEMS documentation "*exogenously* estimated vehicle scrappage and fleet transfer rates." https://www.eia.gov/outlooks/aeo/nems/documentation/archive/pdf/m070(2016).pdf.

> this would seem to represent a very different effect from what might be going on in the CAFE model results.

Bunch goes on to discuss the relationship between sales, scrappage and fleet size in NEMS in the following passage:

> New vehicle sales generally are growing in both scenarios, so economic theory suggests that fleet sizes should also be growing (they are). Specifically, although the Gruenspecht effect logic suggests that increasing new vehicle sales should lead to increased used vehicle scrap rates, the total "value" of the fleet is increasing, so this would suggest an increase in the fleet size. Moreover, new vehicle sales are higher under Existing, so the fleet size should be also.

Bunch makes several claims that are not consistent with available data and the agencies' understanding of how the NEMS model. First, he states that because sales are growing fleet size should also be growing. However, change in fleet size is the result of new vehicle sales less the number of existing vehicles scrapped; if new vehicle sales and used vehicle scrappage rates both increase, the fleet size is not necessarily increasing. Second, he states that the 'Gruenspecht effect logic' suggests that increasing new vehicle sales results in increasing scrappage rates. However the NEMS model does not change vintage-specific scrappage rates endogenously, but takes them as an exogenous input. Thus, the NEMS model does not capture the Gruenspecht effect, and its fleet size projections can only vary from changes in new vehicle sales. Any differences in the projected total fleet scrappage rates Bunch considers later are due to different initial sales of each body style, and therefore a different weighting of the constant body-style- and vintage-specific scrappage rates. This makes the comparison of the fleet size and scrappage rates of the two models not particularly meaningful. However, the difference in the projected sales impacts are worth a second glance. NEMS predicts prices that are at most about $1,000 higher in the Augural than the proposed standards, while the CAFE model predicts prices that are up to approximately $2,500 higher. The difference in the projected costs to meet the CAFE standards is likely the main reason for the difference in the sales outcomes—if the average fuel savings exceed the average incremental cost of the augural standards (relative to the proposal) in the NEMS model, the expected outcome is that sales should be higher in the augural case, as shown.

It is also worth noting Bunch's discussion of the empirical results of the CAFE scrappage model. Bunch purports to calculate the scrappage elasticity relative to new vehicle price increases, but his point of comparison does not hold constant other factors that might impact used vehicle scrappage rates. Instead, Bunch calculates the inter-annual percentage change in the scrappage rates for each regulatory alternative, then calculates the inter-annual change in new vehicle prices for each regulatory alternative, and finally takes the quotient. However, for inter-annual changes in scrappage rates, different projected GDP growth rates and fuel prices will have also played a critical role in the scrappage rates. The better point of comparison would be the incremental percentage decrease in scrappage rates for the augural standard relative to the proposal, over the incremental percentage increase in new vehicle price in the augural standard relative to the proposal for each calendar year. This ensures that the point of comparison holds constant all other factors that determine scrappage, as the regulatory alternatives use the same

GDP growth rate and fuel price projections. When computing the implied scrappage elasticity in this way, the implied elasticities vary between approximates -0.1 and -1.1, with the average being approximately -0.5—which is *more* in line with what Bunch determines reasonable for his incorrect calculations of the NEMS model scrappage elasticities, as cited below:

> Finally, the average values are -0.90 and -0.88 for the Existing and Rollback scenarios, respectively. On one hand, these are reasonably close to the Jacobsen and van Benthem (2015) estimate for scrap elasticity with respect to used vehicle prices. On the other hand, the Bento et al. (2018) estimate was -0.4, and one might expect the elasticity with respect to new vehicle price to be smaller. In any case, these results are not unreasonable.

The implied elasticities from the NEMS model are approximately zero, which is not a surprise since these are merely the result of different new vehicle sales affecting the relative weighting of NEMS' *constant* age-specific scrappage rates.

As discussed above, commenters offered NERA's model and NEMS as points of comparison for NHTSA's sales and scrappage models and their combined implied fleet size. However, since NEMS does not model the scrappage effect, but takes static scrappage rates, it is not a fair point of comparison. NERA's model shows a larger fleet under the Augural standards, providing evidence that the impacts of the sales and scrappage models are ambiguous.

(c) Integration with VMT

In the NPRM the agencies noted that the average VMT by age is constant regardless of instantaneous or cumulative scrappage rates. We noted that this was a limitation of the model, and sought comment on ways to integrate the two effects:

> [O]ur scrappage model assumes that the average VMT for a vehicle of a particular vintage is fixed—that is, aside from rebound effects, vehicles of a particular vintage drive the same amount annually, regardless of changes to the average expected lifetimes. The agencies seek comment on ways to further integrate the survival and mileage accumulation schedules.[1259]

Several commenters suggest that the lack of integration between VMT and scrappage rates is not justified. Some commenters suggested that the VMT should be determined from a household holdings model, while others suggested merely that delayed scrappage under higher standards should increase average mileage accumulation, which will have some feedback for the next year's scrappage rates.

Joshua Linn and other commenters suggest that VMT is determined at the household level and should thus be modelled as such. EDF makes the following comment, which seems to reflect a fundamental misunderstanding of the type of model used to predict the scrappage effect:

[1259] [Text Forthcoming]

> When describing the process whereby a potential new vehicle purchaser chooses to forego buying a new vehicle and continues to drive their existing vehicle, NHTSA's scrappage model ignores the fact that this action shifts VMT from a new vehicle with a higher average mileage per year to a used vehicle with a lower average mileage. Either the driver of this vehicle will drive their older vehicle less, causing overall VMT to decline, or the average mileage of the used vehicle will increase without any need to affect scrappage. By focusing solely on scrappage, and focusing the change in scrappage on those vehicles with the worst fuel economy (i.e., the oldest vehicles), NHTSA essentially shifts new vehicle VMT to the oldest vehicles. According to NHTSA's own rationale, much of the lost VMT from new vehicles will be replaced by vehicles only a few years old. The VMT of these relatively new used vehicles which is then replaced by VMT from older used vehicles, and so on.

The agencies' scrappage model does not capture household choices, but uses aggregate data to predict new vehicle sales and age-specific scrappage rates in response to changes in new vehicle prices. In addition, the scrappage rates of all ages change in response to increases in new vehicle prices, not jnst the oldest vehicles. Further, the household that does not buy a new vehicle but holds onto an existing vehicle instead, in EDF's example, results in one fewer used vehicle supplied to the used market—this will result in an increased price for used vehicles and potentially lead to some used vehicles not being scrapped. Because the VMT schedules the agencies use in modelling show usage declining with age, the agencies' model does assume that younger vehicles that are not scrapped are driven more than older vehicles that are not scrapped.

EDF, IPI, and Honda further argue that mileage accumulation should not be constant under all scrappage rates. Specifically, they suggest that the assumption that average VMT accumulation by age is constant even when scrappage rates decline, results in an *over*estimate of VMT. IPI suggests that the marginally unscrapped vehicles should drag down the average VMT accumulation under higher standards in the following comment:

> Because those schedules assume each vehicle of a certain age and type in the fleet drives a set amount of miles without any adjustment for the increase in total fleet size or vehicle quality (i.e., wear and tear and durability), the finding that the standards cause the fleet size to increase results in a significant increase in total VMT.

The agencies note that mileage accumulation and scrappage are not disjoint. A vehicle that is driven more miles is more likely to be scrapped. However, since the National Vehicle Population Profile (NVPP) data does not track individual vehicles, there is no obvious way to merge individual vehicle odometer readings with those that are scrapped. The agencies hope to continne to investigate data sources that may quantify the joint relationship of the two effects, and better respond to the claims from EDF that "NHTSA presents no data or analysis to justify this assumption." In the meantime, the agencies have adjusted the final rule analysis to conservatively assume that total demand for VMT, not including the rebound effect, should be constant for all regnlatory alternatives, as discussed in Section [xxx], below. This requires that the VMT schedules are no longer constant for all fleet sizes.

(d) Total VMT

Many commenters think that total VMT, not considering rebound miles, should be constant, regardless of the number of new vehicles sold and used vehicles scrapped. NCAT, Global, Auto Alliance, CBD, EDF, IPI, CARB, and Honda all make this argument. CARB makes the following statement suggesting that even a larger fleet size should not increase aggregate demand for VMT (again, not including rebound miles):

> A change in the overall fleet size due to the Augural standards might not in and of itself be problematic, as long as the VMT schedules are adjusted to account for overall travel activity that is distributed over a larger number of vehicles. However, the As-Received version of the [scrappage] model does not adjust VMT schedules, with the result that the additional unscrapped vehicles inflate total VMT proportionally.

The agencies agree that the aggregate demand for VMT should be roughly constant across alternatives, and stated this in the NPRM, where the differences in non-rebound VMT were on the order of 0.4%.

NERA's modelling efforts found similar small decreases in VMT in regulatory alternatives where the standards are relaxed. The Alliance stated:

> Under all three scenarios, vehicle miles traveled ("VMT") decreases relative to the augural standards. This is due primarily to rebound effects. Because NERA was only examining vehicles through MY 2029, the difference in VMT between the alternatives and the augural standards decreases over time, since fewer of the MY 2029 and earlier vehicles are on the road in those later years.

NERA's model used similar assumptions as the NPRM analysis and, like the NPRM results, the NERA model results suggest that it is plausible that total VMT could decline under less stringent standards. A key assumption cominon to NERA's model and the NPRM analysis is that the VMT schedules are constant under all scrappage rates. However, as discussed in Section [xxx] this can potentially overestimate total VMT in the angural case, where vehicles that were marginally scrapped in the proposal are kept on the road.

Presumably, vehicles that are scrapped in the proposal, but not in the augural, are in more disrepair than others in the same age cohort. As a result, these vehicles would on average be driven less, bringing down the average usage of the entire age cohort. This effect could alter the relative size of total VMT under the regulatory alternatives, as Honda notes in the following comment:

> According to our calculations, if the impact of lowering the average cohort's utility is even 0.2% the augural standards would become *safer* than the preferred alternative. We believe that the agencies should consider VMT behavior change as part of an effort to mature and refine the scrappage model.

As Honda suggests, a relatively small reduction in the average VMT schedules for the more stringent regulatory alternatives could result in a change in the direction of the safety impact.

This shows the importance of investigating the linkage between usage and scrappage rates, but also shows that small changes to the total VMT assumptions can have meaningful impacts on the predicted effects of the analysis. Other commenters make similar points.

As noted above, the difference in total non-rebound VMT in the NPRM analysis was only 0.4%. However, CBD notes that this relatively small change in VMT across the alternatives in a single year can result in a large number of cumulative additional miles in more stringent regulatory alternatives:

> While 0.4% sounds small, when the scrappage model's effect it is multiplied by all the VMT that NHTSA includes in its analysis, spanning decades, it becomes highly significant—at least 692 billion additional VMT under the CAFE standards and 894 billion under the CO_2 program, both relative to the preferred alternative.

Since VMT is related to many of the costs and benefits of the program, differences in cumulative VMT of this magnitude can have meaningful impacts on the incremental net benefit analysis. This point was implied by comments from CBD, EDF, NCAT, EAQ, and in a paper published by academics after the issuance of the NPRM.[1260] For this reason, the agencies have opted to constrain total non-rebound VMT across regulatory alternatives.

Such a constraint was suggested by EDF, IPI and other commenters. EDF states the following:

> A sophisticated model is not needed to correct this problem. One only needs to adjust the VMT added by the "scrappage model" so that it matches the VMT lost by the sales response model. Put another way, used vehicles would be used to the same extent as new vehicles since they meet the identical demand (possibly minus a rebound effect).

EDF goes on to suggest some potential issues with implementing this constraint:

> Even this adjustment would still be in favor of the proposal, as it assumes that all the VMT lost from fewer new vehicle sales would be replaced by used vehicle VMT. This assumes that travel is inelastic. This is clearly not the case given NHTSA's position on the rebound effect. NHTSA must first justify the used vehicle response to any change in new vehicle sales. Then, in the unlikely event that this can be done, NHTSA must link the scrappage model to the sales response model to ensure that the combination of the two models does not increase VMT in any calendar year (and probably show a decrease, as the overall cost of driving will have increased).

The agencies disagree that lost new vehicle sales would impact the VMT of the new vehicles that are sold. The agencies do, however, as EDF notes, adjust the VMT of new vehicles to consider changes in the cost per mile of travel. In fact, when fuel prices increase, the agencies assume that owners of all existing vehicles drive less; the reduction will be greater when the vehicles on

[1260] Bento, Antonio M., et al. "Flawed Analyses of U.S. Auto Fuel Economy Standards." Science, vol. 362, no. 6419, 2018, pp. 1119–1121., doi:10.1126/science.aav1458.

the road are less efficient, which seems consistent with what EDF suggests in the last sentence above. The agencies have justified the scrappage effect throughout this discussion, above.

EDF identifies another reason the agencies think a constraint on total VMT is reasonable for purpose of the final rule analysis. The scrappage, sales, and VMT models each have a certain amount of uncertainty associated with it (the uncertainty of the scrappage model is discussed in Section I.A.1.a)(1)(b)(i)(a)), so that when the three models are combined, the uncertainty is compounded. EDF characterizes these results as being inconsistent with economic theory in the comment below:

> We are not aware of any economic arguments which would support such an increase. All that can be said is that NHTSA put data from a variety of sources through a statistical regression and never bothered to see if the results were reasonable or consistent with its own economic theory.

The NPRM analysis discussed total fleet size and VMT at length; the agencies noted that the fleet was 1.5% bigger for the augural standard than the proposal, resulting in 0.4% additional non-rebound VMT in CY2050.[1261] However, given the amount of uncertainty around each of the models, and considering that differences in total VMT can have meaningful impacts on the cost benefit analysis, the agencies are conservatively assuming for the final rule analysis that non-rebound VMT is constant, to constrain the outputs derived from the combination of the three models.

(v) Comments on the Evaluation of Associated Costs and Benefits

(a) Presentation and Valuation of Non-Rebound Miles

IPI and EDF argued that it was inconsistent to exclude the costs and benefits of additional rebound driving but include them for the sales and scrappage effect. For example, EDF stated:

> [W]henever a vehicle is driven an additional mile, there is value associated with that travel. NHTSA completely ignores the value of any additional travel which occurs due to reduced scrappage. Including this value would not be an adequate surrogate for the additional repair costs required to keep older vehicles on the road. Just as NHTSA is now recognizing that rebound VMT is due to drivers' express decision to drive more, any driving of older vehicles in lieu of new vehicles is due to the same choice. To treat these identical choices in 180 degree different manners is of course manifestly arbitrary.

The agencies agree that there is value associated with additional miles driven. The NPRM did not directly attribute costs for the loss of additional miles in the scrappage analysis when the fleet size shrank. The final rule analysis addresses this issue by holding non-rebound total VMT constant across regulatory alternatives. However, contrary to what EDF suggests above, the cost of additional maintenance and repair for otherwise-scrapped vehicles are not directly related to

[1261] FR, Vol 83, No. 165, August 24, 2018, p.43099.

the additional miles. The cost of additional maintenance and repair is incurred because the value of used vehicles has increased. The increase in value of the used vehicles should at least offset the maintenance and repair costs. Any remaining increase in value is offset by lost utility from consumers buying fewer new vehicles.

Holding aggregate non-rebound VMT constant across alternatives addresses IPI's and EDF's concerns that additional miles due to a larger fleet size were not adequately valued. Additional fatalities due to shifting the distribution of those miles ~~towards less safe vehicles~~among vehicles with differing safety should still count in the cost benefit analysis. The marginal utility of a mile driven in a newer vehicle is on average higher than that driven in an older vehicle. The regulation is responsible for the shift in the distribution of miles driven at each vehicle age. ~~Including the additional safety risks and fuel costs accrued from more miles being driven by older vehicles accounts for at least a part of the reduction in the marginal utility of the average mile under more stringent standards.~~

Commented [A335]: CHANGE AS SHOWN: As noted elsewhere, the CAFE model shows that on balance, driving under more stringent standards actually shifts towards newer, safer vehicles due to the rebound effect.

Commented [A336]: REVISE: Ditto above. This entire sentence would need to be re-written in order to be consistent with the CAFE model results.

(b) Scrappage Effects from MY2030 and Beyond

The NPRM analysis considered cost per mile as a continuous variable, and new vehicle prices in discrete levels. This means that persistently higher new vehicle prices in more stringent standards would continue to suppress the scrappage rate of existing vehicles. It also means that higher fuel economies in more stringent scenarios would continue to affect the scrappage rates as well. EDF noted that the cost and benefit accounting that considered the costs and benefits accruing to the remaining lifetimes of MYs 1977-2029 included some of the costs of the scrappage effect due to the higher prices of MYs beyond 2030, but did not include the benefits of the reduced fuel economy for these MYs. EDF proposed that the agencies consider a CY analysis instead of the model year presented in the NPRM:

> [A] 2017-50 CY analysis would include the operation of 2017-2029 MY vehicles through CY 2050. This would include the any scrappage effects on these vehicles through 2050, consistent with the inclusion of new 2050 MY vehicles in the analysis. Some of the operation of all the 2017-2029 MY vehicles would be excluded from the analysis, as these vehicles are not assumed to be scrapped in the Volpe Model until CY 2052-2068. Such an analysis would include the benefits over the clear majority of the operation of 2017-2029 MY vehicles compared to both the shorter calendar year analysis and NHTSA's 1977-2029 MY analysis. It would also include the scrappage effects caused by 2017-2050 MY vehicles through CY 2050. Any scrappage effects would be applied to 2030-2050 MY vehicles, as well as 2017-2029 MY vehicles.

However, as the commenter also notes, a CY analysis would exclude some of the lifetime costs and benefits of improving the fuel economy of MYs impacted by the rule (MYs 2017-2029). For this reason, the agencies do not think that a CY analysis should supplant the MY perspective shown in the NPRM.

EDF presents an alternative to switching to a CY analysis which would exclude the scrappage effects due to differences in the prices and fuel efficiencies of MYs not included in the cost benefit analysis (MY 2030 and beyond):

> An alternative that keeps the model year structure of NHTSA's 1977-2029 MY analysis would be to modify it by removing any scrappage effects occurring in 2030 CY and beyond. This analysis would still have the disadvantage of barely including any vehicles which reflect full compliance with the current and proposed standards in 2025. However, it would at least remove the primary problem with NHTSA's current MY analysis. The impact of including the scrappage effects caused by 2030 and later MY vehicles simply and straightforwardly increases the VMT of used vehicles under the current standards.

The agencies note that previous analyses have not considered the costs and benefits of MYs beyond those which could be a response to the change in the considered set of standards. Part of the reason for this was that future standards are unknown, and without existing standards in place, manufacturers may choose to shift application of fuel saving technologies to increases in vehicle performance or safety.[1262] The CAFE model does not currently simulate such actions, so that including MYs too far into the future may overstate the costs and benefits of the rule.

~~While the agencies disagree that excluding cost and benefits of MYs beyond 2030 is an issue for the cost benefit analysis, w~~ We agree that allowing persistently higher prices and fuel economies of future MYs to impact the scrappage of the on-road fleet but not considering the costs and benefits of those MYs is inconsistent. However, changes to the scrappage model mitigate this issue. As noted in Section I.A.1.a)(1)(b)(i)(c) and I.A.1.a)(1)(b)(ii), updates to the time series strategy and the way that new vehicle fuel economy is modelled in the FRM scrappage model change the form of how new vehicle prices and fuel economy enter the equation. First, addressing the autocorrelation by taking the first difference of variables with first order integration instead of including lags of the dependent variables means that cost per mile variables and new vehicle prices are captured as changes rather than in levels. This means that constant, but higher, new vehicle prices in the augural standards will not continue to impact the scrappage rates of existing vehicles. More specifically, higher prices of MYs 2030 and beyond in the augural case will no longer result in lower scrappage rates for prior MYs. Further, since new vehicle cost per mile is no longer explicitly included, but rather the amount of fuel savings consumers of new vehicles value at the time of purchase is excluded from the new vehicle prices series, differences in new vehicle fuel economies for MYs beyond 2029 will no longer impact the scrappage rates of earlier MYs. This naturally takes care of the concern raised by several commenters that the accounting for costs and benefits due to changes in MYs 2030 and beyond was inconsistent due to the scrappage model.

Commented [A337]: REVISE: EPA's GHG standards do not disappear, and thus would continue to be effective. How does CAFE modeling address that?

Commented [A338]: CHANGE AS SHOWN: This is not EPA policy under the Guidelines for Preparing Economic Analyses. See chapter 5, https://www.epa.gov/sites/production/files/2017-09/documents/ee-0568-05.pdf , p. 5-4: "The ending point of an analysis is the point in time at which the comparison between the baseline and policy scenarios ends. Generally, the duration of important effects of a policy determines the period chosen for the analysis and baseline." EPA's standards, both existing & those finalized in this rule, stay in effect after MY 2025, and continue to be different.

Note that EPA is working on a rule that would require rules from the Office of Air & Radiation to be consistent with the Guidelienes. It may be proposed before the SAFE rule is finalized.

Commented [A339]: REVISE: Again, this does not appear to be true for the EPA standards.

[1262] [Text Forthcoming]

(c) Estimation of the FRM Scrappage Models

(i) Framing Dynamic Scrappage Models in the Literature

(a) How Fuel Economy Standards Impact Vehicle Scrappage

As noted above, any increase in price (net of the portion of reduced fuel savings valued by consumers) will increase the expected life of used vehicles and reduce the number of new vehicles entering the fleet (the Gruenspecht effect). In this way, increased fuel economy standards may slow the turnover of the fleet and the entrance of any regulated attributes tied only to new vehicles. Gruenspecht tested his hypothesis in his 1981 dissertation using new vehicle price and other determinants of used car prices as a reduced form to approximate used car scrappage in response to increasing fuel economy standards.

Commented [A340]: CHANGE AS SHOWN: The effects in principle may be positive or negative.

Greenspan and Cohen (1996) offer additional foundations from which to think about vehicle stock and scrappage. Their work identifies two types of scrappage: engineering scrappage and cyclical scrappage. Engineering scrappage represents the physical wear on vehicles which results in their being scrapped. Cyclical scrappage represents the effects of macroeconomic conditions on the relative value of new and used vehicles—under economic growth the demand for new vehicles increases and the value of used vehicles declines, resulting in increased scrappage. In addition to allowing new vehicle prices to affect cyclical vehicle scrappage à la the Gruenspecht effect, Greenspan and Cohen also note that engineering scrappage seemsed to increase where EPA vehicular-criteria pollutant emissions standards also increased; as more costs ~~go~~ went towards compliance technologies, ~~it becomes more expensive to maintain and repair more complicated parts, and~~ scrappage increasesd. In this way, Greenspan and Cohen identify two ways that fuel economy standards could affect vehicle scrappage: 1) through increasing new vehicle prices, thereby increasing used vehicle prices, and finally, reducing on-road vehicle scrappage, and 2) by shifting resources towards fuel-saving technologies—potentially reducing the durability of new vehicles ~~by making them more complex~~.

Commented [A341]: CHANGE AS SHOWN: Greenspan & Cohen don't say that.

Commented [A342]: CHANGE AS SHOWN: It doesn't seem appropriate to rely on a statistically insignificant effect from a paper whose data are 30-60 years old.

Commented [A343]: CHANGE AS SHOWN: there isn't evidence that complexity has affected durability.

(b) Aggregate vs. Atomic Data Sources in the Literature

One important distinction in literature on vehicle scrappage is between those that use atomic vehicle data (data following specific individual vehicles), and those that use some level of aggregated data (data that counts the total number of vehicles of a given type). The decision to scrap a vehicle is made on an individual vehicle basis, and relates to the cost of maintaining a vehicle, and the value of the vehicle both on the used car market, and as scrap metal. Generally, a used car owner will decide to scrap a vehicle when the value of the vehicle is less than the value of the vehicle as scrap metal, plus the cost to maintain or repair the vehicle. In other words, the owner gets more value from scrapping the vehicle than continuing to drive it, or from selling it.

Recent work is able to model scrappage as an atomic decision due to the availability of a large database of used vehicle transactions. Work by authors including Busse, Knittel, and Zettelmeyer (2013), Sallee, West, and Fan (2010), Alcott and Wozny (2013), and Li, Timmins, and von Haefen (2009) consider the impact of changes in gasoline prices on used vehicle values and scrappage rates. In turn, they consider the impact of an increase in used vehicle values on the scrappage rate of those vehicles. They find that increases in gasoline prices result in a reduction in the scrappage rate of the most fuel efficient vehicles and an increase in the scrappage rate of the least fuel efficient vehicles. This has important implications for the validity of the average fuel economy values linked to model years, and assumed to be constant over the life of that model year fleet within this study. Future iterations of such studies could further investigate the relationship between fuel economy, vehicle usage, and scrappage, as noted in other places in this discussion.

While the decision to scrap a vehicle is made atomically, the data available to NHTSA on scrappage rates and variables that influence these scrappage rates are aggregate measures. This influences the best available methods to measure the impacts of new vehicle prices on existing vehicle scrappage. The result is that this study models aggregate trends in vehicle scrappage, and not the atomic decisions that make up these trends. Many other works within the literature use the same data source and general scrappage construct, including those by Walker (1968), Park (1977), Greene and Chen (1981), Gruenspecht (1981), Gruenspecht (1982), Feeney and Cardebring (1988), Greenspan and Cohen (1996), Jacobsen and van Benthan (2015), and Bento, Roth, and Zhuo (2016.). These works all use aggregate vehicle registration data as the source to compute vehicle scrappage.

Walker (1968) and Bento, Roth and Zhuo (2016) use aggregate data directly to compute the elasticity of scrappage from measures of used vehicle prices. Walker (1968) uses the ratio of used vehicle Consumer Price Index (CPI) to repair and maintenance CPI. Bento, Roth, and Zhuo (2016) use used vehicle prices directly. While the direct measurement of the elasticity of scrappage is preferable in a theoretical sense, the CAFE model does not predict future values of used vehicles, only future prices of new vehicles. For this reason, any model compatible with the current CAFE model must estimate a reduced form similar to Park (1977), Gruenspecht (1981), and Greenspan and Cohen (1996), who use some form of new vehicle prices or the ratio of new vehicle prices to maintenance and repair prices to impute some measure of the effect of new vehicle prices on vehicle scrappage.

(c) Historical Trends in Vehicle Durability

Waker (1968), Park (1977), Feeney and Cardebring (1988), Hamilton and Macauley (1999), and Bento, Ruth, and Zhuo (2016) all note that vehicles change in durability over time. Walker (1968) simply notes a significant distinction in expected vehicle lifetimes pre- and post-World War I. Park (1977) discusses a 'durability factor' set by the producer for each year, so that different vintages and makes will have varying expected lifecycles. Feeney and Cardebring (1988) show that durability of vehicles appears to have generally increased over time both in the U.S. and Swedish fleets using registration data from each country. They also note that the changes in median lifetime between the Swedish and U.S. fleet track well, with a 1.5-year lag in the U.S. fleet. This lag is likely due to variation in how the data is collected—the Swedish

vehicle registration requires a title to unregister a vehicle, and therefore gets immediate responses, where the U.S. vehicle registration requires re-registration which creates a lag in reporting further discussed in Section I.A.1.a)(1)(c)(ii)(b).

Hamilton and Macauley (1999) argue for a clear distinction between embodied versus disembodied impacts on vehicle longevity. They define embodied impacts as inherent durability similar to Park's producer supplied 'durability factor' and Greenspan's 'engineering scrappage' and disembodied effects as those which are "environmental," such as highway safety and migration to the sunbelt, not unlike Greenspan and Cohen's 'cyclical scrappage.' They use calendar year and vintage dummy variables to isolate the effects—concluding that the ~~environmental~~ disembodied factors are greater than any pre-defined 'durability factor.' Some of their results could be due to some inflexibility of assuming model year coefficients are constant over the life of a vehicle, and also some correlation between the observed life of the later model years of their sample and the 'stagflation'[1263] of the 1970's. Bento, Ruth, and Zhuo (2016) find that the average vehicle lifetime has increased 27 percent from 1969 to 2014 by sub-setting their data into three model year cohorts. To implement these findings in the scrappage model incorporated into the CAFE model, this study takes pains to estimate the effect of durability changes in such a way that the historical durability trend can be projected into the future; for this reason, the agencies include a continuous 'durability' factor as a function of model year vintage.

Commented [A344]: CHANGE AS SHOWN: "environmental" implies env. regulation, which is not what H & M describe in their paper.

(ii) Polk/IHS Registration Data

As in the NPRM, NHTSA uses proprietary data on the registered vehicle population from IHS/Polk for the scrappage models. IHS/Polk has annual snapshots of registered vehicles counts beginning in calendar year (CY) 1975 and continuing until CY2017. Notably, the data collection procedure changed in CY2002, which requires some special consideration (discussed below). The data includes the following regulatory classes as defined by NHTSA: passenger cars, light trucks (classes 1 and 2a), and medium and heavy-duty trucks (classes 2b and 3). Polk separates these vehicles into another classification scheme: cars and trucks. Under their schema, pickups, vans, and SUVs are treated as trucks, and all other body styles are included as cars. In order to build scrappage models to support the model year (MY) 2021-2026 light duty vehicle (LDV) standards, it was important to separate these vehicle types in a way compatible with the existing CAFE model.

(a) Choice of Aggregation Level: Body style

Two compatible methods existed by which the agencies could aggregate scrappage rates: by regulatory class or by body style. Since, for CAFE purposes, vans/SUVs are sometimes classified as passenger cars and sometimes as light trucks (depending upon vehicle-specific attributes) and there was no simple way to reclassify some SUVs as passenger cars within the Polk dataset, the agencies chose to aggregate survival schedules by body style. This approach is also preferable because it is consistent with the level of aggregation of the VMT schedules.

[1263] Continued high inflation combined with high unemployment and slow economic growth.

Since usage and scrappage rates are not independent of each other, if average usage rates are meaningfully different at the level of body style, it is likely that scrappage rates are as well.

Once stratified into body style level buckets, the data can be aggregated into population counts by vintage and age. These counts represent the population of vehicles of a given body style and vintage in each calendar year. The difference between the counts of a given vintage and vehicle type from one calendar year to the next is assumed to represent the number of vehicles of that vintage and type scrapped in each year.

(b) Greenspan and Cohen Correction

One issue with using snapshots of registration databases as the basis for computing scrappage rates is that vehicles are not removed from registration databases until the last valid registration expires—for example, if registrations are valid for a year, vehicles will still appear to be registered in the calendar year in which they are scrapped. To correct for the scrappage that occurs during a calendar year, a similar correction as that in Greenspan and Cohen (1996) is applied to the Polk dataset. It is assumed that the real on-road count of vehicles of a given MY registered in a given CY is best represented by the Polk count of the vehicles of that model year in the succeeding calendar year ($Polk_{CY+1}$). For example, the vehicles scrapped between CY2000 and CY2001 will still remain in the Polk snapshot from CY2000 ($Polk_{CY2000}$), as they will have been registered at some point in that calendar year, and therefore exist in the database. Using a simplifying assumption that all States have annual registration requirements,[1264] vehicles scrapped between July 1st, 1999 and July 1st, 2000 will not have renewed registration between July 1st, 2000 and July 1st, 2001, and will not show up in $Polk_{CY2001}$. The vehicles scrapped during CY2000 are therefore represented by the difference in count from the CY2000 and CY2001 Polk datasets: $Polk_{CY2001}$ - $Polk_{CY2000}$.

For new vehicles (vehicles where MY is greater than or equal to CY), the count of vehicles will be smaller than the count in the following year—not all of the model year cohort will have been sold and registered. For these new model years, Greenspan and Cohen assume that the Polk counts will capture all vehicles which were present in the given calendar year and that approximately one percent of those vehicles will be scrapped during the year. Importantly, this analysis begins modeling the scrappage of a given model year cohort in: $CY = MY + 2$,[1265] so that the adjustment to new vehicles is not relevant in the modeling because it only considers scrappage after the point where the on-road count of a given MY vintage has reached its maximum.

[1264] In future analysis, it may be possible to work with State-level information and incorporate State-specific registration requirements in the calculation of scrappage, but this correction is beyond the initial scope of this rulemaking analysis. Such an approach would be extraordinarily complicated as States can have very different registration schemes, and, further, the approach would also require estimates of the interstate and international migration of registered vehicles.

[1265] Calculating scrappage could begin at CY=MY+1, as for most model year the vast majority of the fleet will have been sold by July 1st of the succeeding CY, but for some exceptional model years, the maximum count of vehicles for a vintage in the Polk data set occurs at age 2.

(c) Polk Data Collection Changes

Prior to calendar year 2002, Polk vehicle registration data was collected as a single snapshot on July 1st of every calendar year. All vehicles that are in the registration database at that date are included in the dataset. For calendar years 2002 and later, Polk changed the timing of the data collection process to December 31st of the calendar year. In addition to changing the timing of the data collection, Polk updated the process to a rolling sample. That is, they consider information from other data sources to remove vehicles from the database that have been totaled in crashes before December 31st, but may still be active in State registration records.

The switch to a partially rolling dataset will mean that some of the vehicles scrapped in a calendar year will not appear in the dataset and their scrappage will wrongly be attributed to the year prior to when the vehicle is scrapped. While this is less than ideal, these records represent only some of the vehicles scrapped during crashes and scrappage rates due to crashes should be relatively constant over the 2001 to 2002-time period. For these reasons, the agencies expect the potential bias from the switch to a partially rolling dataset to be limited. Thus, the Greenspan and Cohen adjustment applied does not change for the dataset complied from Polk's new collection procedures. As indicated in [Figure III-1], the scrappage counts computed from the old Polk snapshot series represent vehicles scrapped between July 1st of a given calendar year and the succeeding July 1st, and is computed for CY1976-2000. The new Polk snapshot series represents vehicles scrapped between December 31st of a given calendar year and the succeeding calendar year, and is computed for CY2002-2016.

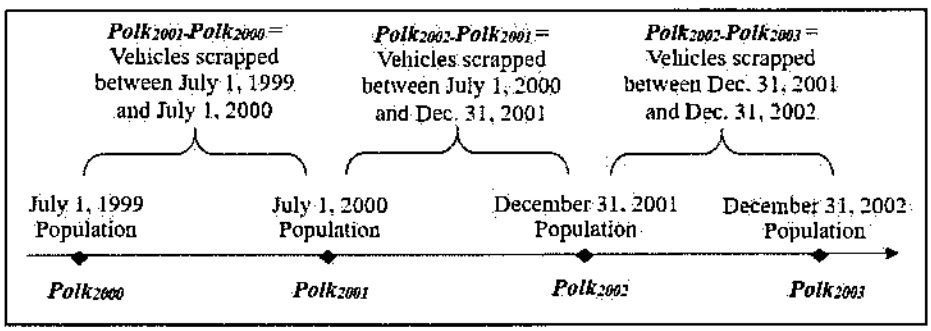

Figure VI-41 - Visualization of Greenspan-Cohen Adjustment and Polk Data Collection Change

There is a discontinuity between the old and new methods so that the computed scrappage for calendar year 2001 represents the difference between the vehicle count reported in $Polk_{CY2002}$ and $Polk_{CY2001}$. $Polk_{CY2001}$ represents all vehicles on the road as of July 1st, 2000, and $Polk_{CY2002}$ represents all vehicles on the road as of December 31, 2001. For this one timespan, the scrappage will represent vehicles scrapped over a 17-month time period, rather than a year. For this reason, the CY2001 scrappage data point is dropped, and because of the difference in the time period of vehicles scrapped under the old and new collection schemes, an

indicator for scrappage measured before and after CY2001 was considered; however, this indicator is not statistically significant, and is dropped from the preferred model.

(d) Updated FRM Dataset

As noted in section II.A.1, some commenters expressed concern about the inability of the scrappage model to predict the scrappage rates of vehicles over age 20. The inability was in large part due to the limited data on the scrappage rates of older vehicles. NHTSA has worked with Polk/IHS to construct some of the historical registration databases using the new methodology for the purposes of other research. As a result, the agency has registration data using *both* Polk collection methods for CY's 2001-2012. Importantly, the old Polk dataset censored data on older vehicles, with CY's 1975-1993 including vehicles ages 0-15 and each successive CY past 1993 adding one additional age to the dataset—so that by 2000 ages 0-22 are included. The new datasets do not censor data on older vehicles, giving these datasets an advantage over the old datasets—for this reason, NHTSA uses as many years of the new data as is available.

The NPRM analysis also used all of the available data using the new methodology at the time of publication (CY's 2005-2015). Since the NPRM was published, NHTSA has gained access to registration data using Polk's new methodology for CY's 2002-2005 and CY's 2016-2017. Table VI-98Table VI-98 shows the calendars years of data in the NPRM and the final rule datasets by age, as well as the total number of data points for each age. There are a total of 330 and 420 data points for ages over 15 in the NPRM and final rule datasets, respectively. That represents almost a 30 percent increase in the number of data points for vehicles over 15, and a 50 percent increase in the number of data points for the oldest vehicles considered in the dataset (ages 27-39). This additional data on older vehicles allows the new scrappage models to better predict the survival rates of older vehicles than the NPRM models.

Table VI-98 - Summary of NPRM vs. Final Rule Datasets by Vehicle Age

Ages	NPRM CYs	Count	Final Rule CYs	Count
0-15	1975-2015	41	1975-2017	43
16	1994-2015	22	1994-2017	24
17	1995-2015	21	1995-2017	23
18	1996-2015	20	1996-2017	22
19	1997-2015	19	1997-2017	21
20	1998-2015	18	1998-2017	20
21	1999-2015	17	1999-2017	19
22	2000-2015	16	2000-2017	18
23	2001-2015	15	2001-2017	17
24	2002-2015	14	2001-2017	17
25	2003-2015	13	2001-2017	17
26	2004-2015	12	2001-2017	17
27-39	2005-2015	11	2001-2017	17

(e) Models of the Gruenspecht Effect Used in Other Policy Considerations

This is not the first estimation of the 'Gruenspecht Effect' for rulemaking policy considerations. In their Technical Support Document (TSD) for its 2004 proposal to reduce emissions from motor vehicles, CARB outlined how they utilized the CARBITS vehicle transaction choice model in an attempt to capture the effect of increasing new vehicle prices on vehicle replacement rates. They considered data from the National Personal Transportation Survey (NPTS) as a source of revealed preferences and a University of California (UC) study as a source of stated preferences for the purchase and sale of household fleets under different prices and attributes (including fuel economy) of new vehicles.

The transaction choice model represents the addition and deletion of a vehicle from a household fleet within a short period of time as a "replacement" of a vehicle, rather than as two separate actions. CARB's final data set consists of 790 vehicle replacements, 292 additions, and 213 deletions; they do not include the deletions, but assume any vehicle over 19 years old that is sold is scrapped. This allowed CARB to capture a slowing of vehicle replacement under higher new vehicle prices. That said, because their model does not include deletions, it does not explicitly model vehicle scrappage, but assumes all vehicles aged 20 and older are scrapped rather than resold. CARB calibrated the model so that the overall fleet size is benchmarked to Emissions FACtors (EMFAC) fleet predictions for the starting year; the simulation then produced estimates that match the EMFAC predictions without further calibration.

The CARB study captures the effect on new vehicle prices on the fleet replacement rates, and offers some precedence for including an estimate of the Gruenspecht Effect. However, because vehicles that exited the fleet without replacement were excluded, we do not learn the effect of new vehicle prices on scrappage rates where the scrapped vehicle is not replaced. New and used vehicles are substitutes, and therefore we expect used vehicle prices to increase with new vehicle prices. And because higher used vehicle prices will lower the number of vehicles whose cost of maintenance is higher than their value, we expect the replacements of used vehicles to slow, but we also expect that some vehicles that would have been scrapped without replacement under lower new vehicle prices will now remain on the road because their value will have increased. The agencies' aggregate measures of the Gruenspecht effect includes changes to scrappage rates both from slower replacement rates, and from slower non-replacement scrappage rates.

(f) Car Allowance Rebate System ('Cash for Clunkers')

On June 14, 2009, the Car Allowance Rebate System (CARS) became law, with the intent to stimulate the economy through automobile sales and accelerate the retirement of older, less fuel efficient and less safe vehicles. The program offered a $3,500 to $4,500 rebate for vehicles traded-in for the purchase of a new vehicle. Vehicles were subject to several program eligibility criteria: first, the vehicle had to be drivable and continuously registered and insured by the same owner for at least one year; second, the vehicle had to be less than 25 years old; third,

the MSRP had to be less than $45,000; and finally, the new vehicle purchased had to be more efficient than the trade-in vehicle by a specified margin. The fuel economy improvement requirements by body style for specific rebates are presented in Table VI-99Table VI-99.

Table VI-99 - CARS Fuel Economy Improvement Required for Rebates by Regulatory Class

	$3,500 Rebate Eligibility	$4,500 Rebate Eligibility
Passenger Car	4-9 MPG Improvement	10+ MPG Improvement
Light Truck	2-5 MPG Improvement	5+ MPG Improvement

The program was originally budgeted for $1 billion dollars and to end on November 1, 2009, but that amount was spent far more quickly than expected and the program received an additional $1.85 billion in funding. Even with that additional funding, the program only lasted through August 25, 2009, expending $2.85 billion on 678,359 eligible transactions. To ensure that the replaced vehicles did not remain on the road, the vehicles were scrapped at the point of trade-in by destroying the engine. While the program resulted in the replacement of more vehicles and at a faster rate than expected, critics have argued that many of the trade-ins would have happened even if the program had not been in place, so that any economic stimulus to the automobile industry during the crisis cannot be attributable to the CARS program. Further, others have argued [SOURCE] that forcing the scrappage of vehicles that could still remain on the road has negative environmental impacts that could outweigh any environmental benefits of the reduced fuel consumption from the accelerated retirement of these less efficient vehicles.

Li, Linn, and Spiller (2010) use Canada as a counterfactual example to identify the portion of CARS trade-ins attributable to the policy, i.e., trade-ins that would not have happened anywhere if the program were not in place. They argue that the Canadian market is largely similar to the U.S. market, in part based upon the fact that 13 to 14 percent of households purchased new vehicles one year pre-recession in both countries. They also argue that the economic crisis affected the Canadian economy in a similar manner as it affected the U.S. economy. While they note that Canada offered a small rebate of $300 to vehicles traded in during January, 2009, hey further note that only 60,000 vehicles were traded in under that program. Using those assumptions, Li, et al., applied a difference-in-difference methodology to isolate the effect of the CARS program on the scrappage of eligible vehicles. Li, et al., found a significant increase in the scrappage only for eligible U.S. vehicles, suggesting they isolated the effect of the policy. They conclude that of the 678,359 trade-ins made under the program, 370,000 of those would not have happened during July and August 2009. They conclude that the CARS program reduced gasoline consumption by 0.9-2.9 billion gallons, at $0.89-$2.80 per gallon saved.

The agencies find the evidence from Li, et al., persuasive toward the inclusion of a control for the CARS program during calendar year 2009. The importance is discussed further

both in the data section, Section [xxx], which provides more evidence for the effect of the CARS program, and in the model specifications Section [xxx], which describes the control used for the effect of the program. This ensures that the measurements of other determining factors are not biased by the exceptional scrappage observed in calendar year 2009.

(iii) Updated Final Rule Modeling

[Text Forthcoming].

(a) Changes to the Time Series Strategy

As discussed in Section (b)(i)(c), the agencies reconsidered the time series strategy for the final rule in response to comments. The first step in doing so is to test the time series properties of the dependent and independent variables. The agencies use the Augmented Dickey-Fuller (ADF) unit root test implemented in the 'CADFtest' R package to test for stationarity.[1266] The agencies find that the logistic scrappage rate is I(0), or stationary in levels. Since the dependent variable is stationary, there is no long-term trend in scrappage rates to capture. Lags of dependent variables need not be included, but their stationary forms should be used in the regressions. The following table summarizes the order of integration of each of the considered regressions; the regression forms represent the form of the variable that is included in the considered models.[1267] All the variables considered are either I(0) or I(1), meaning that they should be run in either levels or first differences, respectively. This significantly simplifies the regressions. Two unintended, positive outcomes of this change in time series strategy are that the coefficients on variables are easier to interpret and the models are less likely to be overfit. In this way, the shift to address concerns about the time series strategy (discussed in Section (b)(i)(c)) also addresses commenter concerns outlined in Section (b)(i)(a).

Table VI-100 - Summary of Order of Integration of Considered Scrappage Variables

Scrappage Factor	Possible Measure(s)	Integration Order(s)	Regression Form(s)
Logistic scrappage rate	LHS variable, measure of scrappage rates	I(0)	Levels
Age	Age defined by the Greenspan/Cohen and di	N/A	Levels
Usage	Not considered (unreliable VMT estimates)	N/A	N/A
Business cycle indicators	GDP growth rates, unemployment rate, per-	I(0), I(1), I(1), I(1)	Levels, difference,
Prices of purchase/use	Used vehicle prices (endogenous--omitted),	N/A, I(1), I(1)	N/A, difference,
Maintenance costs	Maintenance costs (CPI)	I(1)	Diff

Commented [A345]: REVISE: This seems like a potentially serious omission.

[1266] Lupi, Claudio (2019, September 7). Package 'CAFtest.' Retrieved from https://cran.r-project.org/web/packages/CADFtest/CADFtest.pdf.

[48] Note: some of these variables were considered or added in response to comments presented in Sections I.A.1.a)(1)(b)(ii), I.A.1.a)(1)(b)(iii), and I.A.1.a)(1)(b)(iv), and may not be present in the NPRM.

[illegible]	Iron/steel scrap, CPI	I(1)	Difference
Prices/quantity supply of	Nada prices, quantity new vehicles sold	I(1), I(1)	Difference,
Control for quality	Used to new horsepower to weight ratio,	I(0), I(1)	Levels, difference

(b) Final Rule Preferred and Sensitivity Specifications

After consideration of comments on, and subsequent peer review of, the NPRM analysis, the agencies updated the scrappage model specifications for the final rule. Section 0 through I.A.1.a)(1)(c)(iii)(f) discuss other considered specifications and variables. The equation below represents the final form of the scrappage equation included in the central and sensitivity analysis:

$$\ln\left(\frac{S_{MY,CY}}{1-S_{MY,CY}}\right) = \beta_0 * Age_{MY,CY} + \beta_1 * Age^2{}_{MY,CY} + \beta_2 * Age^3{}_{MY,CY} +$$

$$Share\ Remaining_{MY,CY} * (\beta_3 + \beta_4 * Age_{MY,CY}) +$$

$$Diff(New\ Price - FS)_{CY} * (\beta_5 + \beta_6 * Age_{MY,CY} + \beta_7 * Age^2{}_{MY,CY} + \beta_8 * Age^3{}_{MY,CY}) +$$

$$\beta_9 * Diff(Fuel\ Price)_{CY} + \beta_{10} * Diff(CP100M_{MY})_{CY} + \beta_{11} * GDP\ Growth_{CY} +$$

$$(\beta_{12} + \beta_{13} * [Age \geq 25]) * CY2009 + (\beta_{14} + \beta_{15} * [Age \geq 25]) * CY2010 + FE_{MY}$$

Here, "S" represents the instantaneous scrappage rate in a period, so that the dependent variable is the logit form of the scrappage rates. Logit models ensure that predicted values are bounded—in this case between zero and one. It is not possible to scrap more than all the remaining vehicles, nor fewer than zero percent of them, which is illustrated in the graph below:

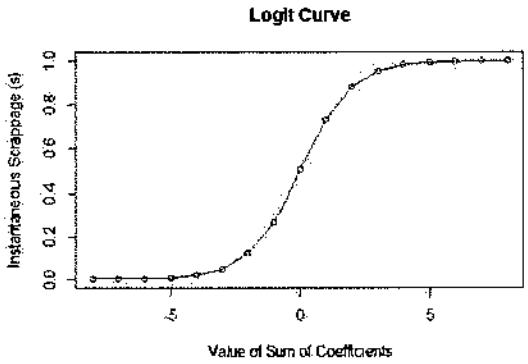

Figure VI-42 – Example Logit Curve

Solving for instantaneous scrappage yields the following:

$$S = \frac{e^{\sum \beta_i X_i}}{1+e^{\sum \beta_i X_i}}.$$

In the equation above, $\sum \beta_i X_i$ represents the right-hand side of the above model specification. Within the right-hand side of the equation, *Age* represents the age of the model year cohort in a specific calendar year, defined by the Greenspan and Cohen adjustment discussed in Section I.A.1.a)(1)(c)(ii)(b). The coefficient on the cubic age term is assumed to be zero for the van/SUV and pickup specifications as this term is not necessary to capture the general scrappage trend for these body styles. *Share Remaining* represents the share of the original cohort remaining at the start of the period. These two components represent the engineering portion of scrappage—the inherent durability of a model year and the natural life cycle of how vehicles scrap out of a model year cohort as the cohort increases with age. The determination of these specific forms is discussed in detail in Section 0.

New Price - FS represents the average price of new vehicles minus 30 months of fuel savings for all body styles. The central aualysis assumes the coefficient on the age interactions for this term are zero for all body styles, but a sensitivity case allows the elasticity of scrappage to vary with age. *Fuel Price* represents the real fuel prices, weighted by fuel share of the model year cohort being scrapped. *CP100M* represents the cost per 100 miles of travel for the specific body style of the model year cohort being scrapped under the current period fuel prices and usiug fuel shares for that model year cohort. These measures capture the response of scrappage rates to new vehicle prices, fuel savings, and to changes in fuel prices that make the used model year cohort more or less expensive to operate. Because these measures are all I(1), as discussed above in I.A.1.a)(1)(c)(iii)(a), the first difference of all of these variables is used in modelling. The other specific modelling considerations that resulted in this form of modelling the new and used vehicles markets are discussed in Sections I.A.1.a)(1)(c)(iii)(d).

GDP Growth represents the GDP growth rate for the current period. This captures the cyclical components of the macro-economy. Section I.A.1.a)(1)(c)(iii)(e) discusses how this specific measure was chosen, and what other measures were considered as alternative or additional independent variables.

CY2009 and *CY2010* represent calendar year dummies for 2009 and 2010 when the CARS program was in effect; this controls for the impact of the program. *[Age ≥ 25]* represents an indicator for vehicles 25 years and older. The interaction of the calendar year dummies with this indicator allows for the effect of the CARS program to be different for vehicles under 25 versus vehicles 25 and older. Since only vehicles under 25 were eligible for the program (see the discussion of the program in Section I.A.1.a)(1)(c)(ii)(f)), this flexibility is important to correctly control for the program.

Finally, FE represents a set of model year fixed effects used to control for heterogeneity across different model years. This is related to the durability and engineering scrappage. The NPRM model did not include fixed effects because it fit a parametric relationship to model year as a continuous variable as a way to capture durability. This change in how the durability effect is modelled is discussed further in Section [xxx]. Further, Section [xxx] discusses trends in the fixed effects and how these are projected forward within the CAFE model.

(c) Modeling Durability Trends over Time

As noted in the NPRM, the durability of successive model years generally increases over time. However, this trend is not constant with vehicle age—the instantaneous scrappage rate of vehicles is generally lower for later vintages up to a certain age, but increases thereafter so that the final share of vehicles remaining converges to a similar share remaining for historically observed vintages. The NPRM parameterized this trend by using the natural log of the model year as a continuous variable interacted with a polynomial form of the age variable—this predicted an increasing but diminishing trend in vehicle durability for younger ages. The analysis for the final rule makes a change that allows more flexibility in durability trends. Below, we consider the survival and scrappage patterns by body style.

There is no clear trend in durability for pickups. Like SUVs/vans, this makes parameterizing by using a form of vintage as a continuous variable problematic. Such a parametric form does not allow for each model year to have its own durability pattern.

There is no clear trend in durability for pickups. Like SUVs/vans, this makes parameterizing by using a form of vintage as a continuous variable problematic. Such a parametric form does not allow for each model year to have its own durability pattern.

Figure [xxx] shows the survival and scrappage patterns of different vintages with vehicle age for cars, SUVs/vans and pickups, respectively. Cars have the most pronounced durability pattern. Figure VI-43Figure VI-43 shows that newer vintages scrap slower at first, but that scrap more heavily so that the final share remaining of cars is more or less constant by age 25 for all vintages.

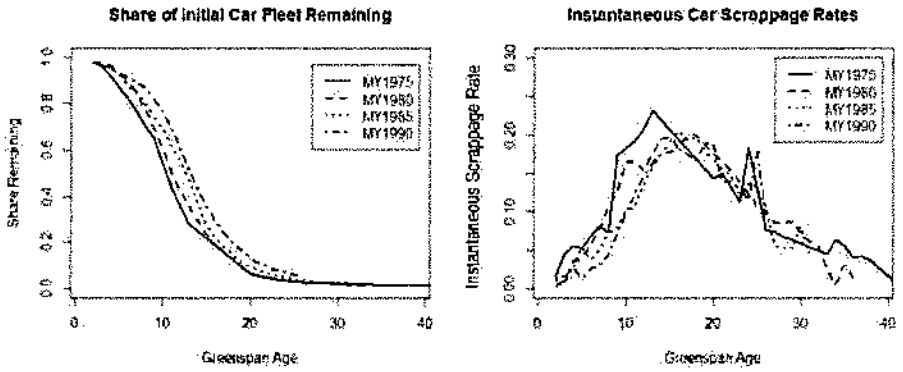

Figure VI-43 - Survival and Scrappage Patterns of Cars by Greenspan Age

SUVs/vans have a less pronounced durability pattern. Model year 1980 actually lives longer than model years 1985 and 1990. This is likely due to a switch of SUVs/vans to be based on car chassis rather than pickup chasses over time. However, through the later model years, the durability trend is more like that of cars. The lack of a continuous trend in durability of SUVs/vans make how this trend is captured particularly important. Below we discuss a change in how the durability trend is modelled for the final rule, which is more flexible than the NPRM model.

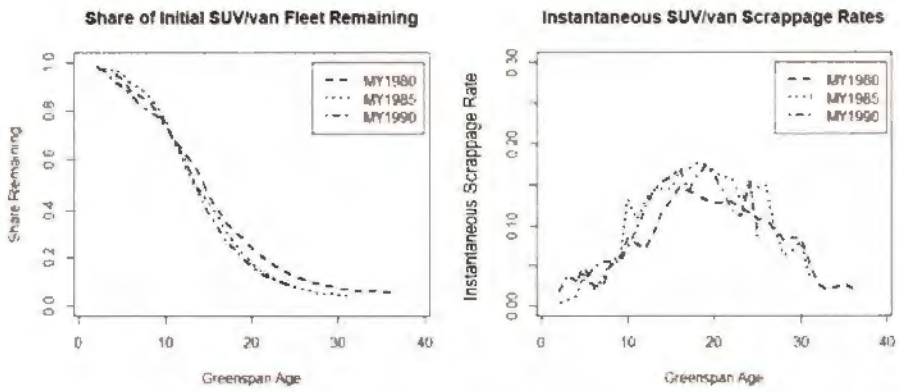

Figure VI-44 - Survival of Scrappage Patterns of SUVs/Vans by Greenspan Age

There is no clear trend in durability for pickups. Like SUVs/vans, this makes parameterizing by using a form of vintage as a continuous variable problematic. Such a parametric form does not allow for each model year to have its own durability pattern.

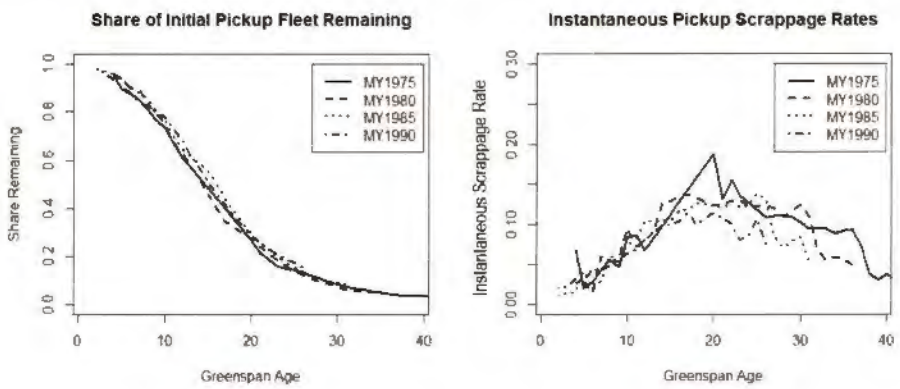

Figure VI-45 - Survival and Scrappage Patterns of Pickups by Greenspan Age

As noted above, the NPRM model used the natural log of model year as a continuous variable interacted with age to capture an increasing but diminishing trend of vehicle durability for the younger ages. However, enforcing a parametric form on a continuous model year excluded the possibility of including model year specific fixed effects and required that durability have a parametric trend with successive vintages. As seen above, SUVs/vans and

pickups certainly do not follow such a trend, so that this constraint was too restrictive, at least for these body styles. The final rule analysis makes an adjustment that allows for an initial increase in the durability of a model year to persist, while including fixed effects and relaxing the parametric assumption.

Instead of regressing the natural log of the vintage share in the remaining models, shown in Table VI-101Table VI-101 through Table VI-103Table VI-103, we use the share remaining in the previous period as an independent variable. Since the logistic instantaneous scrappage rate is stationary (it is independent of the previous periods' logistic instantaneous scrappage rate), the share remaining should not be endogenous. The share remaining models for the final rule include model year specific fixed effects and project a linear trend in durability by fitting a regression through the fixed effects. This latter part still requires a parametric assumption about durability (discussed in Section 0), but not while jointly estimating other coefficients. In this way, the other coefficients should not be biased by projecting the durability trend forwards in the implementation of the scrappage regressions within the CAFE model.

Table VI-101 - Car Relationship of Durability Trend to Age

Variable	Share Remaining, Quadratic	Preferred Share Remaining, Linear	Share Remaining, Constant	NPRM MY Specification
Diff(New Price - Fuel Savings)	-0.0000951*** (0.0000013)	-0.0001009*** (0.0000014)	-0.0000912*** (0.0000020)	-0.0000831*** (0.0000017)
GDP Growth Rate	0.0456642*** (0.0008774)	0.0469495*** (0.0010729)	0.0563901*** (0.0010643)	0.0527792*** (0.0017232)
Diff(Real Gas Price)	-0.4458118*** (0.0200234)	-0.5176484*** (0.0166983)	-0.6428521*** (0.0220153)	-0.2615620*** (0.0263263)
Diff(Used Cost Per 100 miles)	0.0524257*** (0.0038726)	0.0620020*** (0.0034245)	0.0714549*** (0.0045965)	0.0072033 (0.0047873)
Share Remaining	-3.1435300*** (0.0414626)	-3.4186938*** (0.0343009)	-1.4338395*** (0.0256165)	
Share Remaining*Age	0.3120942*** (0.0072003)	0.1806424*** (0.0026794)		
Share Remaining*Age2	-0.0121010*** (0.0005793)			
Log(MY-1959)				-1.5494447*** (.0032710)
Log(MY-1959)*Age				0.0945327*** (.0023435)
Log(MY-1959) *Age2				-0.0024088*** (.0001305)
Age	0.0578317*** (0.0070468)	0.0951732*** (0.0058835)	0.4360045*** (0.0021804)	0.1651640*** (0.0095749)
Age^2	-0.0019635*** (0.0003689)	-0.0063290*** (0.0002880)	-0.0205609*** (0.0001130)	-0.0103672*** (0.0005847)
Age^3	-0.0000414*** (0.0000061)	0.0000472*** (0.0000047)	0.0002313*** (0.0000025)	0.0001654*** (0.0000050)

CY2009, Ages 25+	0.4512855*** (0.0314314)	0.4920502*** (0.0218911)	0.4029622*** (0.0252641)	0.1144864*** (0.0250570)
CY2010, Ages 25+	0.2995697*** (0.0238203)	0.2372077*** (0.0122188)	0.1398496*** (0.0233336)	0.2852590*** (0.0268955)
CY2009	0.0732048*** (0.0190192)	0.2075985*** (0.0094498)	0.0839103*** (0.0121392)	0.2290536*** (0.0172472)
CY2010	0.2273621*** (0.0135031)	0.3150729*** (0.0089111)	0.4052745*** (0.0169191)	0.1095964*** (0.0189317)
Adj-R^2	**0.8989188**	**0.9001046**	**0.8957709**	**0.8746106**
AIC	**213**	**201**	**231**	**371**
Woodridge AC P-Value[1]	**0.0026154**	**0.0145811**	**0.0010401**	**0.0000001**

*** p < 0.001; ** p < 0.01; * p < 0.05; . p < 0.1.

[1]Note: Wooldridge Test For AR(1) Errors in FE Panel Models implemented as 'pwartest' from the R Package 'plm'. The null hypothesis is that there is serial correlation in the errors, so that a p-value<0.05 suggests that the errors are not serially correlated.

Table VI-102 - SUVs/Vans Relationship of Durability Trend to Age

Variable	Share Remaining, Quadratic	Preferred Share Remaining, Linear	Share Remaining, Constant	NPRM MY Specification
Diff(New Price - Fuel Savings)	-0.0000228*** (0.0000013)	-0.0000356*** (0.0000013)	-0.0000299*** (0.0000011)	-0.0000264*** (0.0000032)
GDP Growth Rate	0.0695386*** (0.0012301)	0.0657111*** (0.0009900)	0.0795823*** (0.0010000)	0.0802932*** (0.0010867)
Diff(Real Gas Price)	-0.2764171*** (0.0257452)	-0.4362834*** (0.0278925)	-0.2895806*** (0.0231274)	0.2825669*** (0.0545445)
Diff(Used Cost per 100 Miles)	0.0524134*** (0.0043595)	0.0717750*** (0.0043034)	0.0531272*** (0.0034518)	-0.0237569** (0.0081900)
Share Remaining	0.0297029 (0.0901657)	-3.3452757*** (0.0554430)	0.7119660*** (0.0222985)	
Share Remaining*Age	-0.0621384*** (0.0073936)	0.1825513*** (0.0030923)		
Share Remaining* Age^2	0.0112131*** (0.0003223)			
Log(MY-1959)				-1.6397949*** (.0027097)
Log(MY-1959)*Age				0.2071080*** (0.0020895)
Log(MY-1959) *Age2				-0.0061019*** (0.0000999)
Age	0.2466527*** (0.0063507)	0.0460123*** (0.0055806)	0.4015673*** (0.0015458)	-0.3256119*** (0.0072432)
Age^2	-0.0065623*** (0.0001252)	-0.0029204*** (0.0001212)	-0.0095063*** (0.0000358)	0.0107678*** (0.0003243)
CY2009, Ages 25+	0.3581448*** (0.0206753)	0.6247703*** (0.0191476)	0.3282078*** (0.0248535)	0.1279913* (0.0497896)
CY2010, Ages 25+	0.3022435*** (0.0215352)	0.1385811*** (0.0298242)	-0.0734390** (0.0223489)	0.2482407*** (0.0343923)
CY2009	0.4353784*** (0.0155607)	0.1828926*** (0.0129064)	0.6678445*** (0.0236451)	0.6956480*** (0.0342561)
CY2010	0.0924318*** (0.0167183)	0.2424634*** (0.0126816)	0.3936159*** (0.0158770)	0.0549556* (0.0250943)
R^2	**0.9033051**	**0.9049046**	**0.8845334**	**0.8521034**
AIC	**173**	**160**	**288**	**511**
Woodridge AC P-Value	**0.0035220**	**0.0486846**	**0.0000051**	**0.0000001**

*** p< 0.001, ** p< 0.01, * p < 0.05, . p< 0.1

[1] Note: Wooldridge Test For AR(1) Errors In FE Panel Models implemented as 'pwartest' from the R Package 'plm'. The null hypothesis is that there is serial correlation in the errors, so that a p-value< 0.05 suggests that the errors are not serially correlated.

Table VI-103 - Pickup Relationship of Durability Trend to Age

Variable	Share Remaining, Quadratic	Preferred Share Remaining, Linear	Share Remaining, Constant	NPRM MY Specification
Diff(New Price - Fuel Savings)	-0.0000674*** (0.0000019)	-0.0000816*** (0.0000018)	-0.0000581*** (0.0000017)	-0.0000480*** (0.0000021)
GDP Growth Rate	0.0736057*** (0.0011368)	0.0582337*** (0.0012998)	0.0602333*** (0.0009533)	0.0647886*** (0.0010691)
Diff(Real Gas Price)	-0.2864880*** (0.0334947)	-0.5001835*** (0.0334884)	0.0798291** (0.0299877)	-0.1311305*** (0.0234005)
Diff(Used Cost per 100 Miles)	0.0441250*** (0.0056864)	0.0646677*** (0.0057105)	-0.0097471 (0.0052524)	0.0438846*** (0.0036373)
Share Remaining	-1.5573629*** (0.1003296)	-1.9174078*** (0.0731793)	0.5012308*** (0.0306657)	
Share Remaining*Age	0.1049521*** (0.0054214)	0.1310775*** (0.0034927)		
Share Remaining* Age^2	0.0012152*** (0.0002025)			
Log(MY-1959)				-1.5218779*** (0.0028797)
Log(MY-1959)*Age				0.0725954*** (0.0025993)
Log(MY-1959) *Age2				-0.0017046*** (0.0001111)
Age	0.0776425*** (0.0064930)	0.0528728*** (0.0055778)	0.2629608*** (0.0015738)	0.0222991*** (0.0081504)
Age^2	-0.0023773*** (0.0001126)	-0.0018482*** (0.0000995)	-0.0057176*** (0.0000225)	-0.0004665 (0.0003253)
CY2009, Ages 25+	0.0705278* (0.0354674)	-0.0770359* (0.0343983)	0.1636518*** (0.0337895)	0.0084647*** (0.0210629)
CY2010, Ages 25+	0.3659284*** (0.0136404)	0.4057619*** (0.0129972)	0.2123575*** (0.0153148)	0.2115845*** (0.0108309)
CY2009	0.5757490*** (0.0170277)	0.5752367*** (0.0170742)	0.5852774*** (0.0205956)	0.6417981*** (0.0165040)
CY2010	0.1908829*** (0.0074929)	0.2808360*** (0.0070026)	0.2236518*** (0.0129120)	0.0751358*** (0.0075012)
R^2	**0.9228605**	**0.9193500**	**0.9170718**	**0.8615196**
AIC	**-45**	**-48**	**-32**	**300**
Woodridge AC P-Value	**0.6073232**	**0.6683055**	**0.0516705**	**0.0000001**

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, . $p < 0.1$

[1] Note: Wooldridge Test For AR(1) Errors In FE Panel Models implemented as 'pwartest' from the R Package 'plm'. The null hypothesis is that there is serial correlation in the errors, so that a p-value>0.05 suggests that the errors are not serially correlated.

As Table VI-101Table VI-101 shows, the NPRM specification and both the constant and the quadratic forms of the age interaction with the share remaining variable to capture the durability effect show evidence of autocorrelation. The linear form of the interaction of age and

share remaining does not show evidence of autocorrelation and also has the lowest AIC and highest adjusted R-squared. For these reasons, this is the preferred specification of the durability effect. Since the share remaining coefficient is negative and larger than the positive coefficient on the share remaining interacted with age, a cohort that has a higher share remaining at an early age will have a lower instantaneous scrappage rate in this period until a certain age and then a higher scrappage rate after that age. To find the age where the sign of the share remaining coefficient will switch from predicting a lower instantaneous scrappage rate to a higher one, we must take the ratio of the coefficient on the share remaining variable to the share remaining interacted with age—this suggests that at age 19, the sign of the share remaining variable flips. That is, the instantaneous scrappage rate of cars is predicted to be lower if the share remaining is higher until age 18, after which a higher share remaining predicts a higher instantaneous scrappage rate.

As Table VI-102Table VI-102 shows, the linear interaction of age and share remaining is the only specification of the durability effect for SUVs/vans that do not show autocorrelation in the error structure. The linear interaction of age and share remaining has the lowest AIC and highest R-squared; for this reason, this is the preferred specification of the durability effect for SUVs/vans. The signs for share remaining and share remaining interacted with age show a similar trend as that to cars. Taking the ratio again of the share remaining to the share remaining interacted with age, for ages 0 to 18 a higher share remaining predicts lower instantaneous scrappage, and for ages beyond 18 it predicts a higher instantaneous scrappage rate.

As Table VI-103Table VI-103 shows, all but the NPRM specification of the durability effect for pickups do not show autocorrelation in the error structures. However, similar to cars and SUVs/vans, the linear interaction of age and share remaining has the lowest AIC and highest adjusted R-squared. For this reason, this is the preferred specification for all body styles. Taking the ratio of the coefficient on share remaining to share remaining interacted with age shows that a higher share remaining will predict a lower instantaneous scrappage rate in the next period for ages 0 through 14, but a higher instantaneous scrappage rate for ages 15 and older.

Using the preferred forms of the engineering scrappage rates for each body style as the reference point, Section I.A.1.a)(1)(c)(iii)(d) considers different forms to predict the Gruenspecht effect for each body style. Section 0 uses the preferred engineering and Gruenspecht forms to consider alternative macroeconomic variables to predict the effects of the business cycle. Finally, Section I.A.1.a)(1)(c)(iii)(f) uses the preferred engineering, Gruenspecht and business cycle forms to consider the inclusion of other additional independent variables.

(d) Modeling Impacts of New Vehicle Market on Used Scrappage Rates

Table VI-104

Table VI-104 through

Table VI-106

Table VI-106 show the relationship between car, SUV/van, and pickup scrappage rates and changes in new vehicle price and fuel economies. The agencies consider two methods in response to comments outlined in Section[xxx]: 1) changes in average new vehicle prices net of 30 months of fuel savings (consistent with the technology selection and sales model) and 2) change in average new vehicle prices, change in average fuel prices, changes in new vehicle cost per mile and changes in new vehicle fuel consumption. We allow the elasticity of average new vehicle prices net of 30 months of fuel savings to vary by age by including interaction terms.

Table VI-104 - Relationship of Car Scrappage to New Vehicle Prices and Fuel Economy

Variable	Preferred, Net Fuel Savings, Constant	Net Fuel Savings, Linear	Sensitivity, Net Fuel Savings, Quadratic	Separate Price, Fuel Economy, Cost Per Mile
Diff(New Price - Fuel Savings)	-0.0001009*** (0.0000014)	-0.0001525*** (0.0000016)	-0.0002447*** (0.0000049)	
Diff(New Price - Fuel Savings)*Age		0.0000028*** (0.0000001)	0.0000234*** (0.0000006)	
Diff(New Price - Fuel Savings)*Age^2			-0.0000006*** (0.0000000)	
Diff(New Price)				-0.0001102*** (0.0025360)
Diff(New Cost per 100 miles)				0.3104217*** (0.0203082)
Diff(New Gallons per 100 miles)				0.6786587*** (0.0244078)
GDP Growth Rate	0.0469495*** (0.0010729)	0.0533102*** (0.0008983)	0.0515414*** (0.0010808)	0.0579894*** (0.0011316)
Diff(Real Gas Price)	-0.5176484*** (0.0166983)	-0.6193021*** (0.0177331)	-0.2984000*** (0.0164970)	-1.3561326*** (0.0674843)
Diff(Used Cost per 100 Miles)	0.0620020*** (0.0034245)	0.0948952*** (0.0036206)	0.0101592** (0.0031673)	0.0507081*** (0.0044548)
Share Remaining	-3.4186938*** (0.0343009)	-3.2610500*** (0.0347456)	-3.2047307*** (0.0359759)	-3.0292926*** (0.0518612)
Share Remaining*Age	0.1806424*** (0.0026794)	0.1830840*** (0.0030767)	0.1728009*** (0.0030742)	0.1435656*** (0.0042835)
Age	0.0951732*** (0.0058835)	0.0935496*** (0.0058767)	0.1139102*** (0.0065524)	0.1338257*** (0.0088632)
Age^2	-0.0063290*** (0.0002880)	-0.0055859*** (0.0003005)	-0.0067346*** (0.0003194)	-0.0068805*** (0.0004261)
Age^3	0.0000472*** (0.0000047)	0.0000283*** (0.0000050)	0.0000494*** (0.0000051)	0.0000364*** (0.0000068)
CY2009, Ages 25+	0.4920502*** (0.0218911)	0.3763375*** (0.0272160)	0.3773918*** (0.0262295)	0.3351997*** (0.0281784)
CY2010, Ages 25+	0.2372077*** (0.0122188)	0.0292782* (0.0146548)	0.1973215*** (0.0219700)	0.2797734*** (0.0117004)
CY2009	0.2075985*** (0.0094498)	0.2500054*** (0.0142794)	0.0226063 (0.0150853)	0.1804066*** (0.0167150)

CY2010	0.3150729*** (0.0089111)	0.4262344*** (0.0117008)	0.2643185*** (0.0134019	0.4310161*** (0.0148754)
Adj-R^2	**0.9001046**	**0.8978312**	**0.9018271**	**0.9015194**
AIC	**201**	**220**	**191**	**195**
Woodridge AC P-Value[1]	**0.0145811**	**0.0042689**	**0.0046674**	**0.0040304**

*** p < 0.001, ** p < 0.01, * p < 0.05, . p < 0.1

[1] Note: Woolridge Test For AR(1) Errors In FE Panel Models implemented as 'pwartest' from the R Package 'plm'. The null hypothesis is that there is serial correlation in the errors, so that a p-value<0.05 suggests that the errors are not serially correlated.

Table VI-105 - Relationship of SUVs/Vans Scrappage to New Vehicle Prices and Fuel Economy

Variable	Preferred, Net Fuel Savings, Constant	Net Fuel Savings, Linear	Sensitivity, Net Fuel Savings, Quadratic	Separate Price, Fuel Economy, Cost Per Mile
Diff(New Price - Fuel Savings)	-0.0000356*** (0.0000013)	0.0000261*** (0.0000017)	-0.0000432*** (0.0000095)	
Diff(New Price - Fuel Savings)*Age		-0.0000034*** (0.0000001)	0.0000090*** (0.0000013)	
Diff(New Price - Fuel Savings)*Age^2			-0.0000005*** (0.0000000)	
Diff(New Price)				-0.0000584*** (0.0018598)
Diff(New Cost per 100 miles)				0.2481953*** (0.0121297)
Diff(New Gallons per 100 miles)				0.1813089*** (0.0359516)
GDP Growth Rate	0.0657111*** (0.0009900)	0.0725973*** (0.0006582)	0.0693090*** (0.0014036)	0.0809516*** (0.0014299)
Diff(Real Gas Price)	-0.4362834*** (0.0278925)	-0.3113836*** (0.0214827)	-0.4430938*** (0.0409938)	-0.9867794*** (0.0524833)
Diff(Used Cost per 100 Miles)	0.0717750*** (0.0043034)	0.0508437*** (0.0034454)	0.0693220*** (0.0062875)	0.0049118 (0.0042336)
Share Remaining	-3.3452757*** (0.0554430)	-2.4944456*** (0.0244459)	-3.0893114*** (0.1124436)	-2.5080104*** (0.0482793)
Share Remaining*Age	0.1825513*** (0.0030923)	0.1734217*** (0.0015555)	0.1997850*** (0.0062640)	0.1433111*** (0.0028016)
Age	0.0460123*** (0.0055806)	0.1006019*** (0.0024285)	0.0505098*** (0.0110255)	0.1170863*** (0.0047866)
Age^2	-0.0029204*** (0.0001212)	-0.0037523*** (0.0000499)	-0.0026851*** (0.0002315)	-0.0042930*** (0.0001036)
CY2009, Ages 25+	0.6247703*** (0.0191476)	0.5644086*** (0.0108902)	0.5463005*** (0.0324982)	0.4193102*** (0.0239290)
CY2010, Ages 25+	0.1385811*** (0.0298242)	0.7182072*** (0.0204022)	0.6472086*** (0.0486646)	0.3589860*** (0.0259557)
CY2009	0.1828926*** (0.0129064)	0.3981442*** (0.0148314)	0.2907002*** (0.0163819)	0.4807127*** (0.0203134)
CY2010	0.2424634*** (0.0126816)	0.0010099 (0.0144798)	0.1464127*** (0.0144448)	0.1562764*** (0.0182688)
Adj-R^2	**0.9049046**	**0.8986186**	**0.9074788**	**0.9040243**
AIC	**160**	**205**	**146**	**170**
Woodridge AC P-Value[1]	**0.0486846**	**0.0051432**	**0.1316248**	**0.0013532**

*** p < 0.001, ** p < 0.01, * p < 0.05, . p < 0.1

[1] Note: Wooldridge Test For AR(1) Errors In FE Panel Models implemented as "pwartest" from the R Package "plm". The null hypothesis is that there is serial correlation in the errors, so that a p-value<0.05 suggests that the errors are not serially correlated.

Table VI-106 - Relationship of Pickup Scrappage to New Vehicle Prices and Fuel Economy

Variable	Preferred, Net Fuel Savings, Constant	Net Fuel Savings, Linear	Sensitivity, Net Fuel Savings, Quadratic	Separate Price, Fuel Economy, Cost Per Mile
Diff(New Price - Fuel Savings)	-0.0000816*** (0.0000018)	-0.0000905*** (0.0000034)	-0.0000897*** (0.0000056)	
Diff(New Price - Fuel Savings)*Age		0.0000011*** (0.0000002)	0.0000031*** (0.0000007)	
Diff(New Price - Fuel Savings)*Age^2			-0.0000001*** (0.0000000)	
Diff(New Price)				-0.0000691*** (0.0000023)
Diff(New Cost per 100 miles)				-0.0700731** (0.0258251)
Diff(New Gallons per 100 miles)				0.0888778 (0.0567126)
GDP Growth Rate	0.0582337*** (0.0012998)	0.0629675*** (0.0013398)	0.0736610*** (0.0012428)	0.0697134*** (0.0018850)
Diff(Real Gas Price)	-0.5001835*** (0.0334884)	-0.3690695*** (0.0270939)	-0.2775117*** (0.0489257)	-0.0308644 (0.1293132)
Diff(Used Cost per 100 Miles)	0.0646677*** (0.0057105)	0.0545742*** (0.0044944)	0.0394331*** (0.0080011)	0.0643693*** (0.0066350
Share Remaining	-1.9174078*** (0.0731793)	-1.6788108*** (0.0697507)	-1.9996605*** (0.0820169)	-1.8378628*** (0.0987950)
Share Remaining*Age	0.1310775*** (0.0034927)	0.1189495*** (0.0034509)	0.1255976*** (0.0047108)	0.1160186*** (0.0044129)
Age	0.0528728*** (0.0055778)	0.0784198*** (0.0053503)	0.0654055*** (0.0073660)	0.0852044*** (0.0076383)
Age^2	-0.0018482*** (0.0000995)	-0.0023633*** (0.0000967)	-0.0022842*** (0.0001495)	-0.0026838*** (0.0001337)
CY2009, Ages 25+	-0.0770359* (0.0343983)	0.1707557*** (0.0301821)	0.3712211*** (0.0325056)	0.2832358*** (0.0338548)
CY2010, Ages 25+	0.4057619*** (0.0129972)	0.3217917*** (0.0113259)	0.3532757*** (0.0173499)	0.3053384*** (0.0126055)
CY2009	0.5752367*** (0.0170742)	0.4566868*** (0.0176878)	0.3745724*** (0.0153374)	0.4631546*** (0.0199130)
CY2010	0.2808360*** (0.0070026)	0.2585071*** (0.0101544)	0.2023225*** (0.0113509)	0.2776303*** (0.0111400)
Adj-R^2	**0.9193500**	**0.9239067**	**0.9236018**	**0.9229934**
AIC	**-48**	**-82**	**-66**	**-73**
Woodridge AC P-Value[1]	**0.6683055**	**0.7468139**	**0.8100610**	**0.8961065**

*** p < 0.001, ** p < 0.01, * p < 0.05, . p < 0.1

[1] Note: Wooldridge Test For AR(1) Errors In FE Panel Models implemented as 'pwartest' from the R Package 'plm'. The null hypothesis is that there is serial correlation in the errors, so that a p-value > 0.05 suggests that the errors are not serially correlated.

For all body styles, the specification of the Gruenspecht effect as the change in new vehicle prices net of fuel savings does not show signs of auto-correlated errors. However, for cars and vans/SUVs, the specification which separates the effect of new vehicle prices and fuel economy does show evidence of autocorrelation. For this reason, the changes in new vehicle fuel prices net of fuel savings is the preferred specification of the Gruenspecht effect.

The agencies consider the interaction of the change in average new vehicle prices with vehicle age. This relaxes an assumption that the elasticity of scrappage rates to change in new vehicle prices is constant. For cars and vans/SUVs the linear interaction of change to new vehicle prices net of fuel savings show evidence of autocorrelation. The quadratic interaction of age with change in new vehicle prices shows autocorrelation with cars. For this reason, the agencies consider the constant elasticity of scrappage rates to changes in new vehicle prices to be the preferred specification (as the only specification that does not show evidence of autocorrelation for all body styles). However, we do consider the quadratic form of the elasticity with age as a sensitivity case (even though there is evidence of autocorrelation (but only in the car specification)). This allows the agencies to test the impact of relaxing the assumption around constant elasticity on CAFE model outcomes.

(e) Considering Alternative/Additional Macroeconomic Indicators

Table VI-107Table VI-107 through Table VI-109Table VI-109 show alternative macroeconomic indicators for cars, vans/SUVs and pickups, respectively. The agencies consider unemployment rate and per capita personal disposable income as alternatives to GDP growth rate to capture the cyclical component of the macro economy. The unemployment rate and the per capita personal disposable income are both I(1), so that the first difference of each is the form included. For the car and van/SUV specifications, the specifications replacing GDP growth rate show evidence of autocorrelation in the error structures. For this reason, the GDP growth rate is the preferred specification for the cyclical components of instantaneous scrappage rates, as in the NPRM models.

As discussed in Section (b)(iii)(c), some commenters were concerned with the exclusion of interest rates. In response, the agencies considered including the change in interest rates for the otherwise preferred specification. For vans/SUVs the model has a higher AIC and shows evidence of autocorrelation in the error structures. For pickups, the sign changes on the change in cost per mile when the interest rate is included, which would be an implausible result. Finally, the AIC for cars is nearly identical regardless as to whether the interest rate is included. For these reasons, the agencies continue to exclude the interest rate from the preferred specification.

Table VI-107 - Consideration of Other Macroeconomic Variables on Car Scrappage Rates

Variable	Preferred, GDP	Personal Disposable Income	Unemployment Rate	Interest Rate
Diff(New Price - Fuel Savings)	-0.0001009*** (0.0000014)	-0.0000733*** (0.0000012)	-0.0000878*** (0.0000013)	-0.0000819*** (0.0000021)
GDP Growth Rate	0.0469495*** (0.0010729)			0.0434237*** (0.0009779)
Diff(Per Capita Personal Income)		0.0540494*** (0.0016139)		
Diff(Unemployment Rate)			-0.0409369*** (0.0012396)	
Diff(Real Interest Rate)				-0.0247118*** (0.0010245)
Diff(Real Gas Price)	-0.5176484*** (0.0166983)	-0.7474005*** (0.0242060)	-0.3513089*** (0.0279906)	-0.4670990*** (0.0265618)
Diff(CPM)*100	0.0620020*** (0.0034245)	0.1069816*** (0.0049867)	0.0329797*** (0.0056238)	0.0442433*** (0.0051490)
Share Remaining	-3.4186938*** (0.0343009)	-3.6898124*** (0.0348410)	-2.7131136*** (0.0376662)	-2.6895961*** (0.0417920)
Share Remaining*Age	0.1806424*** (0.0026794)	0.1987995*** (0.0036700)	0.0972431*** (0.0030012)	0.1043302*** (0.0039602)
Age	0.0951732*** (0.0058835)	0.0348470*** (0.0074265)	0.2564925*** (0.0059689)	0.2522376*** (0.0082082)
Age^2	-0.0063290*** (0.0002880)	-0.0029379*** (0.0004242)	-0.0144680*** (0.0003253)	-0.0134434*** (0.0004331)
Age^3	0.0000472*** (0.0000047)	-0.0000133 (0.0000074)	0.0001702*** (0.0000058)	0.0001476*** (0.0000072)
CY2009, Ages 25+	0.4920502*** (0.0218911)	0.6819249*** (0.0400925)	0.1666291*** (0.0201813)	0.4596079*** (0.0291250)
CY2010, Ages 25+	0.2372077*** (0.0122188)	0.2689731*** (0.0177096)	0.0340868* (0.0135936)	0.2121147*** (0.0157184)
CY2009	0.2075985*** (0.0094498)	-0.0209967 (0.0114898)	0.1615951*** (0.0086507)	0.0757698*** (0.0135610)
CY2010	0.3150729*** (0.0089111)	0.3017509*** (0.0081213)	0.4747621*** (0.0126914)	0.1645683*** (0.0153439)
Adj-R^2	**0.9001046**	**0.8945928**	**0.8937426**	**0.9006071**
AIC	**201**	**241**	**247**	**200**
Wooldridge AC P-Value[1]	**0.0145811**	**0.0078107**	**0.0073598**	**0.0272093**

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, . $p < 0.1$

[1] Note: Wooldridge Test For AR(1) Errors In FE Panel Models implemented as 'pwartest' from the R Package 'plm'. The null hypothesis is that there is serial correlation in the errors, so that a p-value > 0.05 suggests that the errors are not serially correlated.

Table VI-108 - Consideration of Other Macroeconomic Variables on SUV/Van Scrappage Rates

Variable	Preferred, GDP	Personal Disposable Income	Unemployment Rate	Interest Rate
Diff(New Price - Fuel Savings)	-0.0000356*** (0.0000013)	0.0000114*** (0.0000011)	0.0000135*** (0.0000011)	-0.0000048** (0.0000018)
GDP Growth Rate	0.0657111*** (0.0009900)			0.0754813*** (0.0015051)
Diff(Per Capita Personal Income)		0.1119676*** (0.0025691)		
Diff(Unemployment Rate)			-0.0357122*** (0.0025642)	
Diff(Real Interest Rate)				0.0413835*** (0.0014089)
Diff(Real Gas Price)	-0.4362834*** (0.0278925)	-0.4396005*** (0.0249243)	-0.4086418*** (0.0195155)	-0.2069678*** (0.0315331)
Diff(Used Cost per 100 Miles)	0.0717750*** (0.0043034)	0.0886952*** (0.0038069)	0.0770162*** (0.0031840)	0.0623373*** (0.0051993)
Share Remaining	-3.3452757*** (0.0554430)	-2.9184918*** (0.0400020)	-2.9366013*** (0.0412519)	-2.4082569*** (0.0601728)
Share Remaining*Age	0.1825513*** (0.0030923)	0.1807410*** (0.0024191)	0.1743960*** (0.0025336)	0.1513631*** (0.0031041)
Age	0.0460123*** (0.0055806)	0.0713979*** (0.0038387)	0.0710222*** (0.0042322)	0.1219095*** (0.0057170)
Age^2	-0.0029204*** (0.0001212)	-0.0034257*** (0.0000796)	-0.0033801*** (0.0000911)	-0.0043665*** (0.0001162)
CY2009, Ages 25+	0.6247703*** (0.0191476)	0.5454099*** (0.0264507)	0.4717237*** (0.0270314)	0.6022986*** (0.0153413)
CY2010, Ages 25+	0.1385811*** (0.0298242)	0.3875841*** (0.0270520)	0.2518103*** (0.0296445)	0.4590574*** (0.0337257)
CY2009	0.1828926*** (0.0129064)	0.4528347*** (0.0204744)	0.1601410*** (0.0221085)	0.4215380*** (0.0183494)
CY2010	0.2424634*** (0.0126816)	0.1198086*** (0.0181028)	0.1605894*** (0.0184065)	0.1780595*** (0.0211695)
Adj-R^2	**0.9049046**	**0.8975155**	**0.8919612**	**0.9030893**
AIC	**160**	**210**	**246**	**175**
Wooldridge AC P-Value[1]	**0.0486846**	**0.0008142**	**0.0003350**	**0.0021439**

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, . $p < 0.1$

[1]Note: Wooldridge Test For AR(1) Errors In FE Panel Models implemented as 'pwartest' from the R Package 'plm'. The null hypothesis is that there is serial correlation in the errors, so that a p-value<0.05 suggests that the errors are not serially correlated.

Table VI-109 - Consideration of Other Macroeconomic Variables on Pickup Scrappage Rates

Variable	Preferred: GDP	Personal Disposable Income	Unemployment Rate	Interest Rate
Diff(New Price - Fuel Savings)	-0.0000816*** (0.0000018)	-0.0000469*** (0.0000015)	-0.0000486*** (0.0000020)	-0.0000642*** (0.0000017)
GDP Growth Rate	0.0582337*** (0.0012998)			0.0630611*** (0.0014781)
Diff(Per Capita Personal Income)		0.0000921*** (0.0000021)		
Diff(Unemployment Rate)			-0.0557550*** (0.0018932)	
Diff(Real Interest Rate)				-0.0089649*** (0.0011178)
Diff(Real Gas Price)	-0.5001835*** (0.0334884)	-0.4553242*** (0.0373881)	-0.2698308*** (0.0262847)	0.0209017 (0.0259166)
Diff(Used Cost per 100 Miles)	0.0646677*** (0.0057105)	0.0717665*** (0.0056154)	0.0478561*** (0.0039224)	-0.0019728 (0.0043907)
Share Remaining	-1.9174078*** (0.0731793)	-2.2916011*** (0.0729752)	-2.4626888*** (0.0656099)	-0.6779801*** (0.0579344)
Share Remaining*Age	0.1310775*** (0.0034927)	0.1388447*** (0.0032202)	0.1437682*** (0.0029693)	0.0892708*** (0.0031062)
Age	0.0528728*** (0.0055778)	0.0328745*** (0.0056070)	0.0289234*** (0.0048643)	0.1492870*** (0.0045037)
Age^2	-0.0018482*** (0.0000995)	-0.0016701*** (0.0001023)	-0.0017219*** (0.0000858)	-0.0034159*** (0.0000816)
CY2009, Ages 25+	-0.0770359* (0.0343983)	0.3080259*** (0.0292822)	0.1936565*** (0.0254670)	0.0805754* (0.0316744)
CY2010, Ages 25+	0.4057619*** (0.0129972)	0.3136625*** (0.0106841)	0.3788601*** (0.0083886)	0.3276065*** (0.0089510)
CY2009	0.5752367*** (0.0170742)	0.3163601*** (0.0158230)	0.3757922*** (0.0177027)	0.5103406*** (0.0187843)
CY2010	0.2808360*** (0.0070026)	0.2272847*** (0.0107818)	0.2175536*** (0.0109206)	0.1509629*** (0.0071344)
Adj-R^2	**0.9193500**	**0.9204734**	**0.9213566**	**0.9223507**
AIC	**-48**	**-56**	**-63**	**-59**
Wooldridge AC P-Value[1]	**0.6683055**	**0.5538016**	**0.5238969**	**0.3997390**

*** p < 0.001, ** p < 0.01, * p < 0.05, . p < 0.1

[1]Note: Wooldridge Test For AR(1) Errors In FE Panel Models implemented as 'pwartest' from the R Package 'plm'. The null hypothesis is that there is serial correlation in the errors, so that a p-value>0.05 suggests that the errors are not serially correlated.

(f) Considering Other Additional Variables

Table VI-110Table VI-110 through Table VI-112Table VI-112 show specifications that consider additional variables not included in the preferred specifications. As discussed in Section (b)(iii)(a), some commenters criticized the fact that maintenance and repair costs were excluded from the scrappage models. In response to comments, and since the maintenance and repair costs are I(1), the agencies considered including the difference in maintenance and repair costs. When included, changes in maintenance and repair costs show the expected sign—when maintenance and repair costs are higher, instantaneous scrappage rates are predicted to be higher (as used vehicles are more expensive to maintain). When included, the AIC is higher for the car and van/SUV specifications. That is, including the change in maintenance and repair costs does not improve the fit of the models. Because of this, and because there is no obvious way to predict future change to maintenance and repair costs (as discussed in the NPRM), the preferred specification continues to exclude maintenance and repair costs.

As discussed in Section (b)(iii)(b), some commenters criticized the exclusion of steel and iron scrap prices from the scrappage models. In response to comments, and since this variable is also I(1), the agencies considered including the change in steel and iron scrap prices. When included, the AIC of cars and vans/SUVs is higher. Further, the car specification includes evidence of autocorrelation in the error structures. In addition, there is no known projection of steel and iron scrappage prices, so that the agencies would have to make projections to include this variable in the scrappage models. Accordingly, the central case continues to exclude steel and iron scrap prices.

As discussed in Section (b)(iii)(d), some commenters and peer reviewers suggested that controlling for aggregate measures of model year cohorts, such as performance, might correct some unexpected signs. The preferred specification already addresses these concerns. Further, because fixed effects are included for model years, we cannot include aggregate model year specific attributes that are constant over the lifetime of the cohort. The agencies do consider the ratio of the average horsepower to weight of a model year cohort to the new vehicle cohort, as this will change along with changes to the horsepower to weight ratio over successive calendar years. Including this variable results in a higher AIC for cars and vans/SUVs and shows evidence of autocorrelation in the errors for these two body styles. For this reason, the preferred specification excludes this metric.

The agencies also considered including new vehicles sales directly as a predictor of instantaneous scrappage rates. Since new vehicle sales are I(1), the difference in new vehicle sales is the included form. Including the change in new vehicle sales results in a higher AIC for cars and vans/SUVs. It also introduces evidence of autocorrelation in the error structure for the car model, and reduces the effect of the change in fuel prices by two orders of magnitude for vans/SUVs. It seems unlikely that the magnitude of the effect of fuel prices would so drastically vary between body styles. For these reasons, the preferred specifications exclude the change in new vehicles sales. The agencies also considered including changes in vehicle stock, but this similarly did not improve the fit of the scrappage models—and doing so limited the ability to link the sales and scrappage models as some commenters suggested (see Sections (b)(iv)(a) and (b)(iv)(b)).

Table VI-110 - Consideration of Additional Variables to Predict Car Scrappage Rates

Variable	Maint/Repair Costs	Iron Steel Scrap Prices	Horsepower to Weight Ratio	New Sales
Diff(New Price - Fuel Savings)	-0.0001087*** (0.0000012)	-0.0000886*** (0.0000017)	-0.0000823*** (0.0000014)	-0.0000459*** (0.0000018)
GDP Growth Rate	0.0502099*** (0.0008717)	0.0493837*** (0.0010346)	0.0285846*** (0.0009415)	0.0736989*** (0.0011973)
Diff(Maintenance/Repair Prices)	0.0313706*** (0.0004552)			
Diff(Iron/Steel Scrap Prices)		0.0003056*** (0.0000112)		
$\frac{(\text{HP to Wgt})_{Used}}{(\text{HP to Wgt})_{New}}$			-0.6628681*** (0.0579964)	
Diff(New Sales)				-0.0800166*** (0.0018404)
Diff(Real Gas Price)	-0.5468416*** (0.0132709)	-0.7639903*** (0.0223095)	-0.2797159*** (0.0263170)	-0.6566466*** (0.0204858)
Diff(Used Cost per 100 Miles)	0.0927501*** (0.0030171)	0.1127770*** (0.0043350)	0.0345106*** (0.0054954)	0.0995253*** (0.0039039)
Share Remaining	-3.8985127*** (0.0359838)	-3.4297719*** (0.0379884)	-2.7571607*** (0.0373302)	-3.3879423*** (0.0386287)
Share Remaining*Age	0.2087872*** (0.0029530)	0.1834034*** (0.0029540)	0.1604072*** (0.0033622)	0.1866613*** (0.0032920)
Age	0.0195811** (0.0060100)	0.0855228*** (0.0056929)	0.1442607*** (0.0072123)	0.1076485*** (0.0067687)
Age^2	-0.0034450*** (0.0002779)	-0.0051356*** (0.0002355)	-0.0069872*** (0.0003721)	-0.0064523*** (0.0003493)
Age^3	0.0000097* (0.0000042)	0.0000181*** (0.0000034)	0.0000379*** (0.0000064)	0.0000472*** (0.0000058)
CY2009, Ages 25+	0.2676016*** (0.0280985)	0.5625097*** (0.0250358)	0.1502497*** (0.0303248)	0.5429818*** (0.0279257)
CY2010, Ages 25+	0.1365566*** (0.0063622)	0.3294714*** (0.0107638)	0.1125183*** (0.0183628)	0.2282722*** (0.0141275)
CY2009	0.0903772*** (0.0114422)	0.1582771*** (0.0161136)	0.3260676*** (0.0128490)	-0.0818500*** (0.0158483)
CY2010	0.4434154*** (0.0073019)	0.2216806*** (0.0099448)	0.3309674*** (0.0122406)	0.2888475*** (0.0100828)
Adj-R^2	**0.8994398**	**.8994063**	**.8982419**	**.8981068**
AIC	**209**	**209**	**226**	**218**
Wooldridge AC P-Value[1]	**0.0140185**	**.0093507**	**.0032309**	**.0081854**

*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$, . $p < 0.1$

[1] Note: Wooldridge Test For AR(1) Errors In FE Panel Models implemented as 'pwartest' from the R Package 'plm'. The null hypothesis is that there is serial correlation in the errors, so that a p-value<0.05 suggests that the errors are not serially correlated.

Table VI-111 - Consideration of Additional Variables to Predict SUV/Van Scrappage Rates

Variable	Maint/Repair Costs	Iron Steel Scrap Prices	Horsepower to Weight Ratio	New Sales
Diff(New Price - Fuel Savings)	-0.0000040*** (0.0000010)	-0.0000274*** (0.0000009)	-0.0000216*** (0.0000016)	0.0000092*** (0.0000017)
GDP Growth Rate	0.0741921*** (0.0009918)	0.0775522*** (0.0005037)	0.0726144*** (0.0010902)	0.0825597*** (0.0012160)
Diff(Maintenance/Repair Prices)	0.0329469*** (0.0005843)			
Diff(Iron/Steel Scrap Prices)		0.0004911*** (0.0000117)		
$\frac{(\text{HP to Wgt})_{Used}}{(\text{HP to Wgt})_{New}}$			-0.6454368*** (0.0623521)	
Diff(New Sales)				-0.0442621*** (0.0020407)
Diff(Real Gas Price)	-0.2798381*** (0.0202630)	-0.6606965*** (0.0169761)	-0.6606965*** (0.0169761)	-0.0026490 (0.0228525)
Diff(Used Cost per 100 Miles)	0.0752267*** (0.0032825)	0.0940092*** (0.0025752)	0.0940092*** (0.0025752)	0.0168291*** (0.0033850)
Share Remaining	-2.5305882*** (0.0291093)	-1.8325438*** (0.0334686)	-2.2211977*** (0.0631267)	-2.2575427*** (0.0445649)
Share Remaining*Age	0.1694026*** (0.0018095)	0.1170733*** (0.0017931)	0.1457258*** (0.0033540)	0.1434476*** (0.0024570)
Age	0.1078797*** (0.0031752)	0.1881191*** (0.0035330)	0.1222155*** (0.0056946)	0.1347715*** (0.0046475)
Age^2	-0.0040207*** (0.0000682)	-0.0058335*** (0.0000752)	-0.0044221*** (0.0001227)	-0.0044682*** (0.0000998)
CY2009, Ages 25+	0.5650111*** (0.0302038)	0.9640493*** (0.0228757)	0.5271317*** (0.0177598)	0.6906880*** (0.0319239)
CY2010, Ages 25+	0.3936247*** (0.0228445)	0.8445298*** (0.0254420)	0.3576068*** (0.0281587)	0.2781208*** (0.0283143)
CY2009	0.3088721*** (0.0188302)	0.1909450*** (0.0157400)	0.4297493*** (0.0179765)	0.3339696*** (0.0204543)
CY2010	-0.0064301 (0.0162095)	-0.0208016 (0.0184329)	0.0730745*** (0.0192466)	0.0092963 (0.0179028)
Adj-R^2	**0.9025463**	**0.8925155**	**0.9000385**	**0.9004698**
AIC	**179**	**244**	**196**	**193**
Woodridge AC P-Value[1]	**0.0487565**	**0.0171649**	**0.0041075**	**0.1046916**

*** p < 0.001, ** p < 0.01, * p < 0.05, . p < 0.1

[1] Note: Woolfdridge Test For AR(1) Errors In FE Panel Models implemented as "pwartest" from the R Package "plm". The null hypothesis is that there is serial correlation in the errors, so that a p-value<0.05 suggests that the errors are not serially correlated.

Table VI-112 - Consideration of Additional Variables to Predict Pickup Scrappage Rates

Variable	Maint/Repair Costs	Iron Steel Scrap Prices	Horsepower to Weight Ratio	New Sales
Diff(New Price - Fuel Savings)	-0.0000487*** (0.0000020)	-0.0000700*** (0.0000020)	-0.0000623*** (0.0000023)	-0.0000307*** (0.0000020)
GDP Growth Rate	0.0700443*** (0.0012637)	0.0566533*** (0.0015045)	0.0673307*** (0.0010741)	0.0893179*** (0.0030757)
Diff(Maintenance/Repair Prices)	0.0228660*** (0.0007310)			
Diff(Iron/Steel Scrap Prices)		0.0001221*** (0.0000210)		
$\frac{(\text{HP to Wgt})_{Used}}{(\text{HP to Wgt})_{New}}$			-0.1333160* (0.0567827)	
Diff(New Sales)				-0.0677648*** (0.0029545)
Diff(Real Gas Price)	-0.1786887*** (0.0174561)	-0.3556862*** (0.0358686)	-0.3922035*** (0.0242830)	-0.2082228*** (0.0317423)
Diff(Used Cost per 100 Miles)	0.0514159*** (0.0026484)	0.0586369*** (0.0059307)	0.0619813*** (0.0038981)	0.0501307*** (0.0047461)
Share Remaining	-1.5629672*** (0.0456494)	-1.5285909*** (0.0747036)	-1.8320104*** (0.0630918)	-1.4612872*** (0.0618426)
Share Remaining*Age	0.1276477*** (0.0016361)	0.1301143*** (0.0036870)	0.1258025*** (0.0030144)	0.1227434*** (0.0027493)
Age	0.0864407*** (0.0032577)	0.0796399*** (0.0057986)	0.0698511*** (0.0048809)	0.0964679*** (0.0045567)
Age^2	-0.0024071*** (0.0000511)	-0.0022014*** (0.0001046)	-0.0023048*** (0.0000815)	-0.0025145*** (0.0000768)
CY2009, Ages 25+	0.1434502*** (0.0195997)	0.0898232** (0.0346743)	0.0576144 (0.0332635)	0.2203882*** (0.0174245)
CY2010, Ages 25+	0.3409843*** (0.0080248)	0.3790355*** (0.0142254)	0.3107753*** (0.0078662)	0.3177551*** (0.0095090)
CY2009	0.3588073*** (0.0146924)	0.5099969*** (0.0188307)	0.5087433*** (0.0155468)	0.3620659*** (0.0186262)
CY2010	0.1000215*** (0.0092390)	0.1611616*** (0.0139655)	0.1979427*** (0.0092854)	0.1663230*** (0.0107195)
Adj-R^2	**0.9254116**	**.9239856**	**.9235905**	**.9273131**
AIC	**-95**	**-83**	**-80**	**-112**
Woodridge AC P-Value[1]	**0.5081298**	**.9660689**	**.6977294**	**0.0298730**

*** p < 0.001, ** p < 0.01, * p < 0.05, . p < 0.1

[1] Note: Wooldridge Test For AR(1) Errors In FE Panel Models implemented as 'pwartest' from the R Package 'plm'. The null hypothesis is that there is serial correlation in the errors, so that a p-value<0.05 suggests that the errors are not serially correlated.

(g) Projecting durability in the CAPE model

The left graphs in Figure VI-46Figure VI-46 through Figure VI-46Figure VI-46 show the fixed effects for the preferred scrappage specifications for cars, vans/SUVs, and pickups, respectively. For all body styles, there is a general downward trend in the fixed effects. This suggests an increase in the durability of successive model years. However, since the panel datasets are not balanced, there is likely potential bias for the fixed effects that include only certain ages. This makes projecting the durability increase from the fixed effects a little more complicated than merely fitting to all fixed effects. First, we must determine what part of this trend is likely due to increases in vehicle durability (and should be projected forward) and which part of the trend may conflate other factors.

The right graphs in Figure VI-46Figure VI-46 through Figure VI-46Figure VI-46 show the average observed logistic scrappage rates by model year for all ages where data exists. As can be seen, the average observed scrappage rates decline dramatically for model years after 1996 for all body styles. There are two reasons this trend exists. First, as Figure VI-46Figure VI-46 through Figure VI-46Figure VI-46 show, the instantaneous scrappage rate generally follows an inverted u-shape with respect to vehicle age. The instantaneous scrappage rates generally peak between ages 15 and 20 for all body styles. Model year 1996 is the first model year which will be at least age 20 at the last date of available data (calendar year 2016). This means that all model years newer than 1996 have likely not yet reached the age where the instantaneous scrappage rate will be the highest for the cohort. Accordingly, the fixed effects could be biased downwards (consistent with the sharper downward slope in the fixed effects for most body styles for model years beyond 1996) because of the unbalanced nature of the panel, and not because of an actual increase in inherent vehicle durability for those model years.

The second reason the average logistic scrappage rates for model years before 1996 is more stable is because each data point in the average has increasingly less effect on the average as more data exists. For model years 1996 and older there are at least 18 data points (we start the scrappage at age 2, by which point effectively all of a model year has been sold), and each will have a smaller effect on the average than for newer model years with fewer observations. For these reasons, the average observed logistic scrappage rate is more constant for model years before 1996. As a result, we do not consider the trend in fixed effects after model year 1996 to rely on enough historical data to represent a trend in vehicle durability, as opposed to a trend in the scrappage rate with vehicle age.

In considering which model year fixed effects should be considered in projecting durability trends forward, another important factor is whether there are discrete shifts in the types of vehicles that are in the market or category of each body style over time. For cars, an increasing market share of Japanese automakers which tend to be more durable over time might result in fixed effects for earlier model years being higher. This trend is shown in the fixed effects in [xxx] Figure VI-46Figure VI-46, which follow a steeper trend before model year 1980.

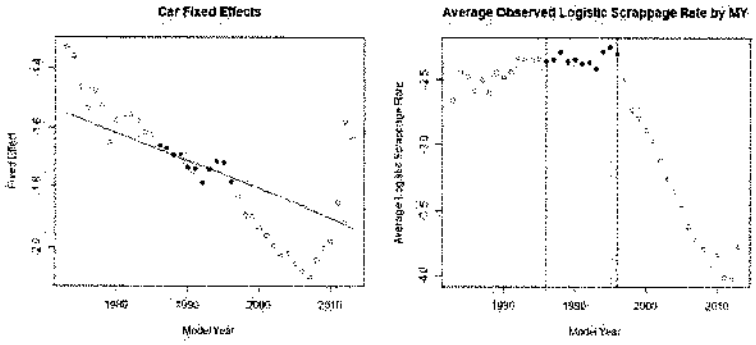

Figure VI-46 - Trends in fixed effects for preferred car specification

For vans/SUVs, earlier model years are more likely to be built on truck chassis (body-on-frame construction) instead of car chassis (unibody construction). Since pickups tend to be more durable, the earlier fixed effects are likely to be lower for vans/SUVs for earlier model years. The 1984 Jeep Cherokee was the first unibody construction SUV.[1268] As Figure VI-47Figure VI-47 shows, the fixed effects before 1986 show inconsistent trends; these are likely due to changes in what was considered a van/SUV over time. For this reason, the agencies build the trend of fixed effects from model years 1986 to 1996.

[1268] https://www.autoguide.com/auto-news/2018/01/10-interesting-facts-from-the-history-of-the-jeep-cherokee.html

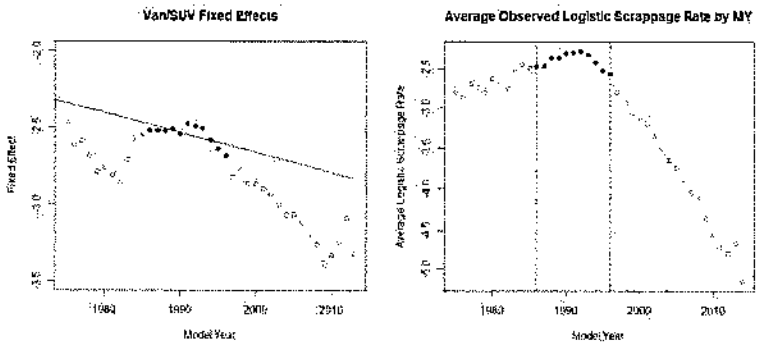

Figure VI-47 - Trends in Fixed Effects for Preferred Van/SUV Specification

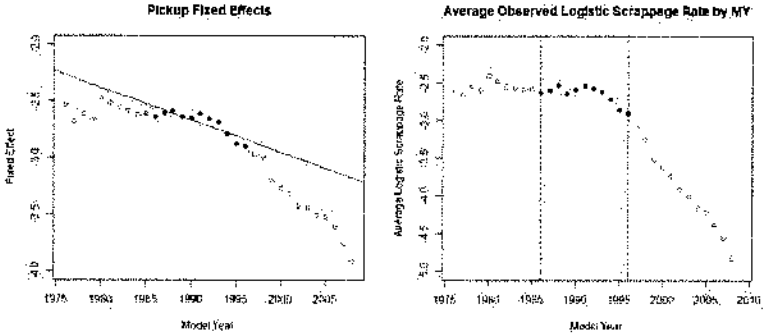

Figure VI-48 - Trends in Fixed Effects for Preferred Pickup Specification

While the trend for pickups and cars could be extrapolated before 1986, the agencies opt to keep the fixed effects included constant for all body styles. Thus, the projections are built from model year 1986 to model year 1996 fixed effects (the filled in data points in Figure VI-48Figure VI-48 through Figure VI-48Figure VI-48). Table VI-113Table VI-113, below, shows the linear regressions shown as the line on the left side of Figure VI-48Figure VI-48 through Figure VI-48Figure VI-48. The durability cap represents the last model year where the durability trend is assumed to persist. We cap the durability impacts at model year 2000, as data beyond this point does not exist for enough ages to determine if durability has continued to increase since this point. The implication of this cap, is that model years after 2000 are assumed to have the same initial durability as model year 2000 vehicles. Since there is a limit to the potential durability of vehicles, this acts as a bound on this portion of the scrappage model.

Table VI-113 - Durability Inputs in the CAFE Model

Beta Coefficients	Inputs	Cars	Vans/SUVs	Pickups
β_{12}	Intercept	21.13195	25.488	54.52891
β_{13}	MY	-0.01141	-0.01364	-0.02879
β_{14}	MY Durability Cap	2000	2000	2000

The durability projections enter the scrappage equation in the CAFE modelling in accordance to the following equation:

$$\ln\left(\frac{S_{MY,CY}}{1-S_{MY,CY}}\right) = \beta_0 * Age_{MY,CY} + \beta_1 * Age^2{}_{MY,CY} + \beta_2 * Age^3{}_{MY,CY} +$$

$$Share\ Remaining_{MY,CY} * (\beta_3 + \beta_4 * Age_{MY,CY}) +$$

$$Diff(New\ Price - FS)_{CY} * (\beta_5 + \beta_6 * Age_{MY,CY} + \beta_7 * Age^2{}_{MY,CY} + \beta_8 * Age^3{}_{MY,CY}) +$$

$$\beta_9 * Diff(Fuel\ Price)_{CY} + \beta_{10} * Diff(CP100M_{MY})_{CY} +$$

$$\beta_{11} * GDP\ Growth_{CY} + \beta_{12} + \beta_{13} * MY_{MY} - \text{ifelse}(MY_{MY} > \beta_{14}, \beta_{13} * (MY_{MY} - \beta_{14}), 0)$$

The intercept enters as a constant added to the predicted logistic of the instantaneous scrappage rate. The model year slope enters as the model year for all model years older than 2000 and enters as 2000 for all model years 2000 and newer.

Once the predicted logistic scrappage rate is calculated in the CAFE model (including the projections of the fixed effect portion of the equation), the future population of model year cohorts can be predicted. The instantaneous scrappage can be calculated directly from S. It identifies the share of remaining vehicles in each calendar year that are scrapped in the next year. The population of vehicles in the next calendar year can be calculated as follows:

$$Population_{MY,CY+1} = Population_{MY,CY} * (1 - s_{MY,CY}).$$

This process is iteratively calculated at the end of the CAFE model simulation to determine the projected population of each model year in each future calendar year. This allows the calculation of vehicle miles travelled, fuel usage, pollutant and CO_2 emissions, and associated costs and benefits. The CAFE model documentation further details how the scrappage model is projected within the simulations.[1269]

(h) Updates to the Decay Function

The scrappage models described above fit the historical data of car and truck scrappage well, but when used to project the scrappage of future model years they over-predict the remaining cars and trucks for ages greater than 30 in an unrealistic manner. Nearly six percent

[1269] [Text Forthcoming]

of the MY2015 van/SUV fleet and eight percent of the pickup fleet is projected to persist until age 40. This is unrealistic, and likely due to the fact that the agencies do not observe enough model years for those ages and over-predict the impact of durability increases for those ages. For this reason, we are using the curves with an accelerated decay function to predict instantaneous scrappage beyond age 30 for pickups and SUVs/vans. The implementation and parameter stricture of the decay function have not changed since the NPRM model. Table VI-114Table VI-114, below, shows the inputs used for the final rule analysis.

Table VI-114 - Decay Function Inputs

Beta Coefficients	Inputs	Cars	Vans/SUVs	Pickups
β_{15}	Decay Age	30	30	30
β_{16}	Final Survival Rate	0.01	0.025	0.025

The final survival rate has not changed since the NPRM, but the input *Decay age* has changed. In the NPRM, the decay function was specified to begin after age 20, while the decay function begins after age 30 in the final rule analysis. This input change was possible because the scrappage model for the final rule predicts shares remaining in line with observed historical trends through age 30, rather than through age 20. This improvement in the model fits for older ages is driven both by the shift of the modelling of the durability effect discussed in Section 0 and the increase in available data on the scrappage rates of older vehicles discussed in Section I.A.1.a)(1)(c)(ii)(d). Overall, this outcome suggests that the final rule model predicts the scrappage rates of older vehicle better than the NPRM model.

As in the NPRM, the decay function is implemented in the model using the following conditions:

If (age<β_{15}),

$$S = \frac{e^{\sum \beta_i X_i)}}{1 + e^{\sum \beta_i X_i)}}$$

And:

$$Population_{MY,CY+1} = Population_{MY,CY} * (1 - S_{MY,CY}).$$

If (age>=β_{15}),

$$Population_{MY,CY+1} = Population_{MY,CY=\beta_{15}} * exp^{rate*t}$$

Where:

$$t = (age + 1 - \beta_{15})$$

And:

$$rate = \frac{ln\left(\frac{(\beta_{16})}{Population_{MY,CY=\beta_{15}}}\right)}{40 - \beta_{15}}$$

Here, the population for ages beyond the start age of the decay function depends on the population of the cohort at that start age and the final share expected for that body style at age 40. The rate of decay necessary to make the final population count equal that observed in the historical data is applied.

(iv) Projections and Implications for Lifetime VMT

[Text Forthcoming]

(4) The Rebound Effect

(a) The Rebound Effect in the NPRM

The fuel economy rebound effect—a specific example of the well-documented energy efficiency rebound effect for energy-consuming capital goods—refers to the tendency of motor vehicles' use (as measured by vehicle-miles traveled, or VMT) to increase when their fuel economy is improved and, as a result, the cost per mile (CPM) of driving declines. Amending and establishing CAFE and CO_2 standards at a lower degree of stringency than the baseline level will lead to comparatively lower fuel economy for new cars and light trucks, thus increasing the amount of fuel consumed to travel each mile. The resulting increase in CPM will lead to a reduction in VMT over the lifetime of new vehicles, an example of the rebound effect working in reverse. In the NPRM, the agencies assumed a fuel rebound effect of 20 percent, meaning that a 5 percent decrease in fuel economy would result in a one percent decrease in the annual number of miles driven at each age over a vehicle's lifetime.

Many of the comments received on different components of the CAFE model can be traced back to the agencies' rebound selection. The agencies recognize that the value selected for the rebound effect influences overall costs and benefits associated with the regulatory alternatives under consideration as well as the estimates of lives saved under various regulatory alternatives, and that the rebound estimate, along with fuel prices, technology costs, and other analytical inputs, is part of the body of information that agency decision-makers have considered in determining the final levels of the CAFE and CO_2 standards. The agencies also note that the rebound effect diminishes the economic and environmental benefits associated with increased fuel efficiency.

For the analysis supporting the NPRM, the agencies conducted a thorough re-examination of the basis for the estimate of the fuel economy rebound effect used to analyze the impacts of CAFE and CO_2 emission standards for model years 2012-16 and 2017-21. This was prompted by three developments. First, more recent updates of the 2007 study by Small and Van

Dender that had provided the basis for assuming the 10 percent rebound effect used in those previous analyses reported larger values. Second, projected growth in the income measure used in those authors' 2007 study, which was anticipated to reduce the magnitude of the rebound effect over the future period spanned by those analyses, did not occur during the decade following the 2007 study's publication. Finally, extensive new research on the rebound effect had become available since those previous analyses were conducted, and while its findings were mixed, many of those more recent studies reported values significantly above the agencies' previous 10% estimate.

In the NPRM, the agencies first summarized estimates of the fuel economy rebound effect for light-duty vehicles in the U.S. from studies conducted through 2011, when the agencies originally surveyed research on this subject. As the accompanying discussion in the proposal indicated, the research available through 2011 collectively suggested that the rebound effect was likely to fall in the range from 20 percent to 25 percent, although the then-recent study by Small and Van Dender (2007) pointed to smaller values, particularly for future years. The agencies then identified 16 additional studies of the rebound effect that had been conducted since their original survey, and the NPRM discussed the various approaches they used to measure the magnitude of the rebound effect, their data sources and estimation procedures, reported findings, and strengths and weaknesses of each study.

Based on this re-examination, the agencies concluded that currently available evidence did not appear to support the 10 percent estimate relied upon in previous rules, and identified a value of 20 percent as more representative of the totality of evidence, including both the research covered by the earlier and more recent studies examined in the NPRM. While acknowledging the wide range of estimates reported in more recent research—which extended from zero to more than 80 percent—the agencies noted that the central tendency of recent estimates appeared to lie in the same 20-25 percent range suggested by their extensive review of earlier research. The agencies also recognized that a 20 percent estimate differed markedly from the 10 percent estimate used in the regulatory analyses for the 2010 and 2012 final rules, but noted that it represented a return to the value NHTSA originally used to analyze the impacts of CAFE standards for model years prior to 2011.

(b) Comments on the Rebound Effect Used in the NPRM

The agencies received numerous comments on the decision to revise their previous estimate of the rebound effect, virtually all of which echoed a few common arguments. First, commenters generally agreed that the most appropriate measure for the agencies to rely on is the current long-run fuel economy rebound effect for U.S., although a few suggested that using an estimate of its short-run value might be preferable.[1270] However, many commenters argued that some of the more recent studies the agencies relied upon to support the revised 20 percent estimate may have limited relevance to the appropriate measure for analyzing the current rule, and that the agencies should place more emphasis on those that commenters asserted were more appropriate to rely upon.

[1270] For example, *see* Resources for the Future, NHTSA-2018-0067-11789, p. 30. Prominent among those arguing that a short- to medium-term rebound effect is more appropriate for the agencies' analysis is IPI, NHTSA-2018-0067-12213, p. 61.

To identify the most relevant research, some commenters proposed applying various selection criteria to choose which studies were most appropriate to rely on when estimating the value of the rebound effect to use in this analysis. While commenters proposed using certain criteria as "filters"—that is, to eliminate any studies that did not meet those criteria—they also suggested applying other criteria to emphasize studies with particular features they argued made them more relevant to identifying the current value of the rebound effect for the U.S.[1271] Among these suggested criteria were the following:

- Exclude estimates based upon data from outside the U.S.;
- Include only estimates based upon "more recent" data, usually taken to mean those published within approximately the last decade;
- View estimates based on the U.S. 2009 National Household Travel Survey skeptically, or exclude them from consideration completely;
- Emphasize estimates derived from vehicle use and fuel economy data spanning multiple years (such as aggregate time-series or panel data), while according less weight to those based on a single-year cross section (such as most household survey data);
- Emphasize estimates of the rebound effect that measure the response of vehicle use to variations in fuel efficiency, rather than in fuel cost per mile driven or fuel price per gallon;
- Emphasize estimates that rely on identification strategies that account for potential endogeneity in fuel economy (as would result, for example, if households with high levels of demand for travel purchase vehicles with higher fuel economy);
- Emphasize estimates based on measures of vehicle use obtained from odometer readings; and
- Emphasize estimates that explicitly control for purchase prices of new vehicles in order to account for changes in new vehicle prices due to CAFE standards.

A few commenters illustrated how applying these criteria could reduce the large number of published studies of the rebound effect to a limited subset that suggested a smaller value than 20 percent.[1272] Using multiple criteria to exclude or de-emphasize studies that did not meet all of those applied, these commenters argued that the most appropriate value for this analysis was closer to (or possibly even

[1271] *See* for example IPI, NHTSA-2018-0067-12213, pp. 58-64; EDF, NHTSA-2017-0069-0574, pp. 16-19; California Office of the Attorney General et al., NHTSA-2017-0069-0625, p. 4; States of California et al. and the Cities of Oakland et al., NHTSA-2018-0067-11735, p. 78; Resources for the Future, NHTSA-2018-0067-11789, p. 3; CARB, NHTSA-2018-0067-11873, p. 120; Aluminum Association, NHTSA-2018-0067-11952, p. 5; NCAT, NHTSA-2018-0067-11969, p. 34; and North Carolina Department of Environmental Quality, NHTSA-2018-0067-12025, p. 12, among others.

[1272] One example is Gillingham, NHTSA-2018-0067-12403, pp. 16-30.

below) the 10-percent estimate the agencies used for the previous rulemaking.[1273] However, one commenter noted that applying these criteria individually to exclude any estimates not meeting them had almost no effect on formal measures of the central tendency (the mean and median values) of the remaining estimates.[1274] This commenter suggested that only by applying two or more of these criteria jointly and excluding any studies that did not meet all of those applied could the universe of research on the rebound effect be reduced to a subset supporting a lower value than the 20 percent figure the agencies used to analyze the NPRM.

Commenters also identified several additional recent studies that were not included in the agencies' review of recent evidence for the NPRM, and suggested revised interpretations of the empirical estimates reported in two studies that had been included (the agencies also clarified a third). Commenters represented these additional studies as generally supporting lower values than the agencies' revised 20 percent estimate, although this appeared to be a selective interpretation of some of the results they reported.[1275] Other commenters asserted that the two most commonly-demonstrated features of the rebound effect are that it varies directly with fuel prices and declines in response to rising income over time, and argued that the latter suggests that a declining value is likely to be more appropriate for analyzing the longer-term impacts of this final rule.[1276]

Some commenters suggested that the rebound effect is asymmetrical, meaning that drivers are more responsive to price increases than price decreases. These commenters asserted that the asymmetrical nature of the rebound effect favors a lower estimate.[1277] Similarly, other commenters suggested that the rebound effect had to be lower than 20 percent because congestion would limit additional driving.[1278]

(c) Agencies' Response to Comments on the NPRM

In response to commenters who argued that the agencies' estimate of the rebound effect should be reduced, because research that incorporates the effects of congestion or allows asymmetrical responses to price changes suggests lower values, the agencies note that, for the

[1273] *See* for example IPI, NHTSA-2018-0067-12213, pp. 58-64; EDF, NHTSA-2017-0069-0574, pp. 16-19; California Office of the Attorney General et al., NHTSA-2017-0069-0625, p. 4; and CARB, NHTSA-2018-0067-11873, p. 120, among others.

[1274] Alliance of Automobile Manufacturers, NHTSA-2018-0067-12386, Attachment.

[1275] For example, some commenters (e.g., Gillingham, NHTSA-2018-0067-12403, Table 2, p. 24) represented the recent analysis of vehicle use data from Texas by Wenzel and Fujita as reporting a rebound effect of 8-15 percent, which appears to be based on those authors' estimates of the response of vehicle use to changes over time in fuel prices alone. This range appears to ignore those same authors' estimates of the sensitivity of vehicle use to variation in fuel costs per mile, which provides a more direct measure of the fuel economy rebound effect because it incorporates fuel economy as well as fuel prices. Those estimates range from 7-40 percent, with most falling in the interval from 15-25 percent; *see* Wenzel and Fujita (2018), Table 4-12, p. 38.

[1276] *See* particularly Small, NHTSA-2018-0067-7789, p. 3.

[1277] EDF, NHTSA-2017-0069-0574, Comment, 37-38.

[1278] For example, the South Coast Air Quality Management District argued that, logistically, rebound cannot exist in Southern California because "any rebound effect will only worsen congestion in Southern California, such a result cannot be predicted." NHTSA-2018-0067-11813 at [].[].

final rule's analysis, those factors would be difficult and perhaps even inappropriate to incorporate in their analysis. In the case of congestion, the agencies note that their estimate of the rebound effect—like research on the rebound effect in general—represents a change in aggregate VMT, and has no clear implication about how that change in travel is likely to be distributed over times of the day or geographic locations.[1279]

As for possible asymmetry in the response of vehicle use to changes in driving costs, the CAFE model applies a single estimate of the rebound effect for all changes in cost-per-mile, and cannot accommodate a rebound effect that varies with the magnitude or direction of changes in driving costs, which would be necessary to capture asymmetrical or non-linear responses to cost changes. The agencies also remind commenters that this rule will result in an increase in driving costs, for which the research they cite generally suggests a *larger* value of the rebound effect is appropriate. In any case, using a different estimate of the rebound effect to analyze impacts of raising and lowering standards would not promote consistency or replicability, both desirable characteristics of regulatory analysis.

The agencies decided to include the previously omitted studies raised by commenters in their rebound analysis supporting the final rule, but do not feel that they suggest a value different from that used to analyze the proposal. Adding these studies to the list of recent research discussed in the NPRM, deleting one unpublished analysis, and revising the entries for selected studies to reflect more accurately the values reported by their authors produces a more extensive catalog of recent research, which is summarized in *Table VI-115Table VI-115* below.

[1279] The agencies' estimate of increased congestion costs associated with additional driving due to the rebound effect implicitly assumes that increased driving will be distributed according to current travel patterns, producing similar proportional increases at various hours of the day and geographic locations. Such an assumption is made out of necessity to model congestion and noise; the agencies acknowledge that the rebound effect is unlikely to affect vehicle use in such a uniform fashion.

Table VI-115 – Recent Estimates of the Rebound Effect for Light-Duty Vehicles

Authors (Date)	Nation	Time Period	Data	Range of Estimates
Barla *et al.* (2009)	Canada	1990-2004	10 Canadian provinces	8-20%
Bento (2009)	U.S.	2001	150,000 household vehicles	21-38%
Waddud (2009)	U.S.	1984-2003	U.S income quintiles	1-25%
Hymel et al. (2010)	U.S.	1966-2004	50 U.S. states	16-24%
Gillingham (2011)	California	2001-09	1 million vehicles	1%
Anjovic and Haas (2012)	E.U.	1970-2007	6 E.U. nations	44%
Greene (2012)	U.S.	1966-2007	annual aggregate values	8-12%
Su (2012)	U.S.	2009	45,000 households	11-19%
Wang *et al.* (2012)	Hong Kong	1993-2009	annual aggregate values	45%
Linn (2013)	U.S.	2009	230,000 household vehicles	20-40%
Frondel and Vance (2013)	Germany	1997-2009	2,165 households	46-70%
Liu (2014)	U.S.	2009	1,420 households	39-40%
Gillingham (2014)	California	2001-09	5 million vehicles	22-23%
Weber and Farsi (2014)	Switzerland	2010	8,000 household vehicles	19-81%
Gillingham et al. (2015)	Pennsylvania	2000-2010	7 million vehicles	8-22%
Hymel & Small (2015)	U.S.	2003-09	50 U.S. states	4-18%
West *et al.* (2015)	U.S.	2009	166,000 new vehicles	0%
DeBorger et al. (2016)	Denmark	2001-11	23,000 households	8-10%
Stapleton et al. (2016)	Great Britain	1970-2011	annual aggregate values	13-23%
Langer et al. (2017)	Ohio	2009-13	229,000 driver-months	12%
Stapleton et al. (2017)	Great Britain	1970-2012	annual aggregate values	22-30%
Wenzel and Fujita (2018)	Texas	2005-2010	32 million vehicles	7-40%
Knittel and Sandler (2018)	California	1996-2010	36 million vehicles	5-27%

As evidenced in *Table VI-115Table VI-115*, studies continue to have a wide range of estimates, but collectively the research looks remarkably similar to the historical estimates. The newer studies suggest that a plausible range for the rebound effect is 10-50 percent. The central tendency of this range appears to be roughly 30 percent.

In response to comments proposing the application of specific criteria to eliminate or reduce the consideration accorded to studies without certain features thought to increase the relevance of their findings, the agencies note that measuring the rebound effect is both conceptually and technically challenging, and that analysts have used many different approaches in an attempt to surmount these challenges. The agencies' view is that each of the studies included in its previous survey and in *Table VI-115Table VI-115* above provides some useful evidence on the likely value of the rebound effect, and while all have some conceptual or theoretical weaknesses, each nevertheless provides some useful insights into the appropriate magnitude of the rebound effect for the current analysis.

As a general approach to estimating parameters that are uncertain, the agencies prefer to rely on the totality of empirical evidence, rather than restricting the available evidence by categorically excluding or according less weight to that do not meet selection criteria that may not be widely agreed upon. From this perspective, analyses that rely on different measurement approaches, data sources, and estimation procedures all have the potential to provide valuable information for choosing the most representative value. The agencies also view sound measurement strategies and careful empirical analysis using reliable data as equally important features when compared to a study's vintage or geographic scope. Examining the widest possible range of research also enables useful comparisons and "cross-checks" on the estimates that individual studies report.

Notwithstanding this more inclusive perspective, the agencies endorse certain of the characteristics preferred by commenters, although the agencies view them as indicators of a strong study, rather than a bright-line test of whether to accord it any weight rather than discarding it from consideration. Specifically, the agencies agree with many commenters that both the extended time span encompassed by their analysis of the impacts of CAFE and CO_2 standards and the long expected lifetimes of vehicles subject to this final rule means that estimates of the long-run rebound effect are most relevant for purposes of the final rule analysis.[1280] The agencies also agree with commenters that estimates based upon more recent data are generally preferable, but nevertheless note that older studies that combine careful analysis with unusually reliable or novel data can offer evidence that remains useful.[1281] The agencies also concur with some commenters' argument that estimates of the rebound effect that are derived from the relationship of vehicle use to fuel efficiency, rather than to fuel cost per mile or gasoline prices, are likely to provide more direct measures of the fuel economy rebound effect itself, which is the desired parameter for the purposes of this analysis. Finally, the agencies generally view identification strategies and econometric methods that account or control for potential endogeneity in fuel economy as likely to provide more reliable estimates.

In contrast, the agencies view other criteria proposed by commenters as unnecessarily restrictive, particularly when they are used to disqualify otherwise informative research from consideration. For instance, categorically excluding from consideration non-U.S. studies—which the agencies agree should be treated cautiously—seems likely to exclude useful evidence, particularly recognizing some of those studies' access to unusually reliable data on vehicle use and fuel economy and use of sophisticated econometric analysis. In addition, many foreign studies have been conducted in nations with income levels comparable to the U.S., and in some cases levels of auto ownership that are beginning to approach U.S. levels. Furthermore, driving

[1280] Most of the vehicles affected by today's standards will remain on the roads for at least a decade, with a significant fraction surviving considerably longer. As such, long-run estimates are more likely to reflect the lifetime mileage accumulation of the new fleet than either short-run or medium-run estimates. Furthermore, a long-run rebound estimate better reflects the cumulative impact of successive CAFE and CO_2 standards such as those adopted by the agencies beginning as early as 2010.

[1281] One example is the study by Greene et al. (1999), which used advanced econometric analysis of unusually detailed and reliable data on household demographic and economic characteristics, household members' use of individual vehicles, and fuel purchases to estimate the response of households' use of individual vehicles to their actual on-road fuel economy, and its implications for total household driving.

habits throughout the U.S. are not homogenous. In fact, some regions in the U.S. may exhibit driving habits that more closely resemble those in some foreign nations than driving patterns in other regions of the U.S.[1282]

In response to some commenters' recommendation that the agencies more heavily weigh studies using data spanning multiple years than those relying on data for a single year, the agencies note that household surveys, the most common form of data for a single year, provide cross-sectional variation in vehicle use and other characteristics that is helpful for identifying the desired long-run measure of the rebound effect. Household surveys are also an important source of information that enable analysts to measure the response of individual vehicles' use to variation in their fuel economy, while also controlling adequately for household characteristics that affect travel patterns and vehicle use. Household survey data can also enable analysts to identify the vehicle substitution patterns within multiple-vehicle households that are increasingly responsible for producing the rebound effect, while even modest-scale household surveys include many more observations than are typically available in aggregate time-series or panel data.

These strengths of course need to be balanced against the potential drawbacks of relying on a one-time snapshot of households' behavior during a single time period. Surveys also frequently rely on owner-reported estimates of vehicle use and usually require analysts to impute vehicles' fuel economy ratings from limited and sometimes incomplete information on the specific vehicle models and vintages that households report owning. One result is that estimates of the rebound effect derived from household survey data may be based on inaccurate estimates of vehicles' use and fuel economy. Assuming the errors in measuring these variables are random, the errors would increase the uncertainty surrounding the estimates of the rebound effect, but would not bias the estimate.

In contrast, studies using nationwide aggregate or average measures of vehicle use and fuel economy or fuel cost rarely provide adequate independent variation to support reliable estimates of the respouse of vehicle use to variation in fuel economy, even where extended time series are available, while State-level measures of these variables are subject to potentially extreme measurement error that can compromise estimates of these relationships.[1283] Moreover, controlling for the many other demographic and economic factors likely to affect vehicle use using national or even State-level aggregate data presents difficult challenges.

Finally, the agencies note that no single selection criterion proposed by commenters noticeably reduces the central tendency displayed by the universe of estimates of the rebound effect, and multiple criteria must be applied simultaneously to restrict the universe to a subset of studies that points toward a significantly lower value than the 20 percent estimate the agencies

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[1282] For example, drivers in Overland Park, Kansas likely respond to changes in fuel prices and fuel economy differently than drivers in Manhattan, New York.

[1283] For example, State-level estimates of travel by individual vehicle classes such as cars and light-duty trucks often exhibit implausible year-to-year variability due to the measurement procedures states employ and the difficulty of distinguishing among different types of vehicles. At the same time, the potential geographic "mismatch" between State-level vehicle use and fuel sales complicates any effort to measure fuel efficiency or fuel costs at the State level.

used to analyze the proposal. Applying multiple criteria drastically reduces the number of studies that remain available to guide the agencies, while at the same time discarding potentially valuable information provided by research those criteria exclude from consideration.[1284] Doing so would thereby necessarily reduce the confidence that the agencies can have in the resulting estimate.

Regarding some commenters' assertion that the rebound effect is known to decline in response to rising income, and that this observation warrants using a lower value for long-term future evaluation of the standards' effects, the agencies note that some evidence based on household and vehicle use surveys suggests that the rebound effect increases with the level of household vehicle ownership, which is itself highly correlated with income. Together with forecasts of limited future growth in most measures of U.S. household income, this finding casts some doubt on whether the rebound effect is likely to decline over the time period spanned by the agencies' analysis.[1285]

The agencies also note that one of the studies cited in *Table VI-115Table VI-115* above (DeBorger et al., 2016) finds that the decline in the fuel economy rebound effect with income reported in the earlier analysis by Small and Van Dender (2007) -on which the agencies relied in reducing their original estimate of the rebound effect to 10 percent—results entirely from a reduction in drivers' sensitivity to fuel prices as their incomes rise, rather than from any effect of rising income on the sensitivity of vehicle use to fuel economy.[1286] This latter measure—which DeBorger et al. find is quite small and has not changed significantly as incomes have risen over time—is the most direct measure of the fuel economy rebound effect, so their analysis calls into question its widely-assumed sensitivity to income.

Finally, because there is not a clear consensus around a single rebound estimate within the literature, the agencies believe it is important to benchmark their analysis with other large scale surveys of the literature published by neutral observers. In one early survey, Greening, Greene, and Difiglio (2000) reviewed studies that estimated the rebound effect for light-duty vehicles in the U.S., concluding that those relying on aggregate time-series data found it was likely to range from 10-30 percent, while those using cross-sectional analysis of household vehicle use suggested a larger rebound effect, in the range of 25-50 percent.[1287] Sorrell et al. (2009) found that the magnitude of the rebound effect for personal automobile travel is likely to

[1284] As an illustration, excluding non-U.S. studies reduces the number of recent analyses surveyed in the proposal from 15 to 8, while eliminating those that rely on the 2009 National Household Travel Survey (NHTS) discards another 5, leaving only 3.

[1285] For example, the widely cited IHS Markit Long-Term Macroeconomic Outlook for Spring 2019 projects that per Capita disposable personal income in the U.S. will grow at 1.6 percent annually over the next 30 years; *see* Federal Highway Administration, Forecasts of Vehicle Miles Traveled (VMT): Spring 2019, Table 2, available at https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.cfm.

[1286] DeBorger, B., Mulalic, I., and Rouwendal, J., "Measuring the rebound effect with micro data: A first difference approach." *Journal of Environmental Economics and Management*, 79 (2016), pp. 1-17.

[1287] Greening, L.A., Greene, D.L. and Difiglio, C., "Energy efficiency and consumption—the rebound effect—a survey." *Energy Policy*, Vol. 28 (2000), pp. 389-401.

fall in the 10-30 percent range, with some evidence suggesting that the lower end of that range might be most appropriate.[1288]

Most recently, a meta-analysis of 74 published studies of the rebound effect conducted by Dimitropoulos et al. (2018) estimated that the long-run rebound effect ranges from 22-29 percent when measured by the response of vehicle use to variation in fuel efficiency (the authors' preferred measure), from 21-41 percent when it is measured using the variation fuel cost per unit distance, and from 25-39 percent using fuel price per gallon.[1289] The authors concluded that "the magnitude of the rebound effect in road transport can be considered to be, on average, in the area of 20%," but noted that the long-run estimate was about 32 percent.[1290] A subsequent published study by these same authors (Dimitropoulos et al. (2018)) concludes that the most likely estimate of the long-run rebound effect is in the range of 26-29 percent, but could range from as low as 15 percent to as high as 49 percent at income levels, development densities, and fuel prices that are currently representative of the U.S.[1291]

(d) Selecting a Value of the Rebound Effect for Evaluating the Impacts of this Rule

After reviewing the evidence on the rebound effect previously summarized in the NPRM, comments the agencies received, other recent studies of the rebound effect that were not summarized in the NPRM but suggested by commenters, and published surveys of literature, a reasonable case can be made to support values of the rebound effect at least as high as 30 percent. The totality of evidence, without categorically excluding studies on grounds that they fail to meet certain criteria, and evaluating individual studies based on their particular strengths, suggests that a plausible range for the rebound effect is 10-50 percent. The central tendency of this range appears to be at or slightly above its midpoint, which is 30 percent. Considering only those studies that the agencies believe are derived from unusually reliable data, employ identification strategies that are likely to prove effective at isolating the rebound effect, and apply rigorous estimation methods suggests a range of approximately 10-45 percent, with most of their estimates falling in the 15-30 percent range.[1292]

[1288] Sorrell, Steve, John Dimitropoulos, and Matt Sommerville, "Empirical Estimates of the Direct Rebound Effect: A Review," *Energy Policy* 37(2009), pp. 1356–71.

[1289] Dimitropoulos, Alexandros, Walid Oueslati, and Christina Sintek, "The rebound effect in road transport: a meta-analysis of empirical studies," Paris, OECD Environment Working Papers, No. 113; *see* esp. Table 5, p. 25 (and accompanying discussion).

[1290] *Id.* at 28.

[1291] Dimitropoulos, Alexandros, Walid Oueslati, and Christina Sintek, "The Rebound Effect in Road Transport: A Meta-Analysis of Empirical Studies," *Energy Economics* 75 (2018), pp. 163-79; *see* esp. Table 4, p. 170, Table 5, p. 172 (and accompanying discussion), and Appendix B, Table B.V., p. 177.

[1292] As indicated previously, these are the selection criteria proposed by commenters with which the agencies concur. In chronological order, the studies the agencies feel best meet those criteria include Greene et al. (1997), Small and Van Dender (2007) and subsequent updates by Hymel, Small, and Van Dender (2010,2015), Linn (2016), Anjovic and Haas (2012), Gillingham (2014), and DeBorger et al. (2016). Other studies the agencies believe warrant serious consideration because they offer some or most of these same advantages include those by Liu et al. (2014), Knittel and Sandler (2018), and Wenzel and Fujita (2018).

At the same time, the agencies conclude that a reasonable case can also be made to support values of the rebound effect falling in the 5-15 percent range. This argument relies on using the criteria proposed by commenters to restrict the studies considered to include recently published analyses using U.S. data, and to accord the most weight to research that relies on measures of vehicle use derived from odometer readings, controls for the potential endogeneity of fuel economy, and estimates the response of vehicle use to variation in fuel economy itself, rather than to fuel cost per distance driven or fuel prices. This approach suggests that the rebound effect is likely in the range from 5-15 percent, and is more likely to lie toward the lower end of that range. The agencies note that estimates of very low or no rebound effect cited by some commenters are either misinterpretations of the findings reported by their authors, or do not represent measures of the fuel economy rebound effect.[1293]

Finally, the agencies note that surveys of evidence on the rebound effect have consistently found that the most appropriate estimate falls in the range of 10-40 percent. These findings have remained surprisingly consistent over time, despite a rapidly expanding universe of empirical evidence that includes estimates drawn from more diverse settings, and reflects continuing improvements in the data they rely upon, an expanding range of strategies for identifying the rebound effect and distinguishing it from other influences on vehicle use, and advances in the econometric procedures analysts use to estimate its magnitude.

For the aforementioned reasons, the agencies have elected to retain the 20 percent rebound effect used to analyze the effects of the NPRM on vehicle use and fuel consumption for analyzing the comparable effects of this final rule. As explained above and in the NPRM, older research suggests a rebound of 20 to 25 percent. The new research in *Table VI-115Table VI-115* supports a similar—or even larger—range. Extensive survey studies support a rebound at or above 20 percent. As such, the agencies feel 20 percent is a reasonable—and probably even conservative—estimate of the totality of the evidence. While a lower estimate may be reasonable under certain circumstances, the agencies are uncomfortable making the requisite assumptions regarding which specific criteria should be used to identify relevant studies and relying on a subset of the literature for the central analysis. However, recognizing the uncertainty surrounding the rebound value, we also examine the sensitivity of those estimated impacts to values of the rebound ranging from 10 percent to 30 percent, both in isolation and in conjunction with plausible variation in other key parameters.

(5) Vehicle Miles Traveled (VMT)

VMT directly influences many of the various effects of fuel economy and CO_2 standards ~~that decision-makers consider in determining what levels of standards to set~~. For example, fuel

Commented [A346]: **REVISE:** Multiple comments in this VMT section below for editorial clarifications, and technical comments on the write-up.

Commented [A347]: **CHANGE AS SHOWN:** Suggest deleting as Section VIII is the appropriate place to discuss how each agency considered setting the final standards.

[1293] For example, some commenters misinterpret Greene's (2012) inability to identify a statistically significant estimate of the response of vehicle use to variation in fuel economy as evidence that its true value is zero. Similarly, some commenters misinterpret the result reported by West et al. (2017) that buyers of more fuel-efficient vehicles did not increase their driving as evidence that fuel economy itself has no effect on vehicle use, when—as the study's authors and some commenters acknowledge—it reveals instead that buyers regarded those vehicles as providing inferior transportation service and drove them less as a consequence. Because the agencies repeatedly insist that vehicle attributes other than fuel economy will not change as a consequence of this rule, those authors' finding is of limited or no relevance to the analysis supporting this rule.

savings is a function of a vehicle's efficiency, miles driven, and fuel price. Similarly, factors like criteria pollutant emissions and fatalities are direct functions of VMT. In the CAFE model, VMT is the product of average usage per vehicle in the fleet and fleet composition, which is itself a function of new vehicle sales and vehicle retirement decisions, otherwise known as scrappage. These three components—average vehicle usage, new vehicle sales, and older vehicle scrappage—jointly determine total VMT projected for ~~in~~ each alternative.

Commented [A348]: REVISE: This is not EPA's understanding of how VMT is projected for each alternative. In contrast to the description here, our understanding is that the total non-rebound VMT is constant across alternatives, and is therefore independent of the three factors listed.

As the following discussion explains, today's VMT analysis provides aggregate results comparable to other well-regarded VMT estimates. However, because the agencies' analysis looks at the incremental costs and benefits across alternatives (see section [xxx]), it is more important that the analysis capture the variation of VMT across alternatives than accurately to predict total VMT ~~consumption~~ within a scenario. As such, the agencies note that today's VMT estimates are logical, consistent, and precise across alternatives. Furthermore, as will be described in further detail below, while the agencies, in response to comments, have decided to modify their approach to calculating VMT and to use different VMT estimates than those used in the NPRM, the general trends between alternatives are comparable.

Commented [A349]: REVISE: 'general trends' in incremental costs and benefits across alternatives would presumably include fatalities and fuel savings – both of which are substantially changed (i.e. not comparable) with the NPRM.

Commenters addressed a number of topics related to the total amount of estimated VMT, the incremental differences in estimated VMT between regulatory alternatives, and per-vehicle VMT estimates in the NPRM analysis. In general, commenters felt that the NPRM's VMT numbers were inaccurate and should not be relied on for the analysis.[1294] Some commenters were more specific and argued that the total amount of estimated VMT projected in the NPRM started at too low a level, and increased too much over the years simulated. Similarly, some commenters argued that the agencies' estimates were too different from other recognized estimates and suggested that the agencies benchmark VMT projections to other sources to ensure both a consistent starting point and comparable VMT throughout the calendar years analyzed.

A few commenters objected to the underlying mileage accumulation schedules, which form the basis for per-vehicle VMT estimates in CAFE Model simulations. Such commenters speculated that revisions to these schedules undertaken in 2016 might be the reason for discrepancies in total VMT. Other commenters were less concerned about how VMT was computed within each scenario but were apprehensive about differences in VMT estimates across regulatory alternatives. For instance, Honda argued that, "[a]ssuming all other parameters are held constant—and excluding the rebound effect—it is not obvious why one scenario should have different total VMT than another."[1295] While commenters generally provided few specific recommendations about the level to which VMT estimates should be constrained among alternatives, several commenters argued that VMT projections would benefit from consideration of travel demand modeling.

The agencies carefully assessed all comments. To address them, the agencies have revised their calculation of estimated VMT in two, significant respects. First, in response to comments regarding the mileage accumulation schedules, the agencies have revised the schedules using panel data. Second, to deal with commenters' concerns with the fluctuation of

Commented [A350]: REVISE: Specific data source should be cited.

[1294] *See, e.g.*, Securing America's Energy Future, NHTSA-2018-0067-11981 at 37-38.
[1295] Honda, NHTSA-2018-0067-11818, at 17.

estimated "non-rebound" VMT across regulatory alternatives, the agencies have created a method that constrains "non-rebound" VMT across regulatory alternatives. The agencies believe these two changes collectively resolve the substantive issues raised by commenters. The total VMT for the final rulemaking (FRM) analysis now aligns with estimates of the Federal Highway Administration (FHWA) and the only differences in VMT between alternatives is attributable to changes in the fleet's fuel economy. The following sections discuss these changes in detail.

(a) Integration of sales, scrappage, and VMT

Additionally, some commenters (RFF, IPI, NRDC) argued that a superior, and perhaps even necessary, approach would be to incorporate a model that considers jointly the decision to buy, use, and retire vehicles at the household level. As RFF posited "a household makes decisions about its vehicle ownership and use jointly: people don't buy new vehicles or get rid of existing ones without considering how these actions will affect the use of their vehicles."[1296] IPI further argued that "[i]n sum, VMT is influenced by vehicle choice and vehicle choice is influenced by VMT. And a 'unified model of vehicle choice and usage' is necessary."[1297] While the agencies agree that a joint household consumer choice model—if one could be developed adequately and reliably to capture the myriad circumstances under which families and individuals make decisions relating to vehicle purchase, use and disposal—would reflect decisions that are made at the household level, we do not agree that it is necessary, or necessarily appropriate, to model the national program at that scale in order to produce meaningful results that can be used to inform policy decisions. The most useful information for policymakers relates to national impacts of potential policy choices. No other element of this analysis occurs at the household level, and the error associated with allocating specific vehicles to specific households over the course of three decades would easily dwarf any error associated with the estimation of these effects in aggregate. We have attempted to incorporate estimates of changes to the new and used vehicle markets at the highest practical levels of aggregation, and worked to ensure that these effects produce fleetwide VMT estimates that are consistent with the best, current projections given our economic assumptions. While future work will always continue to explore approaches to improve the realism of CAFE/CO_2 simulation, there are important differences between small-scale econometric studies and the kind of flexibility that is required to assess the impacts of a broad range of regulatory alternatives over multiple decades. We have read and evaluated the comments on the NPRM, incorporating many suggestions that we believe improve the fidelity of this analysis—taking particular care to be conservative with our analysis. The modifications we have made in response to these comments are described below (and in the RIA).

Commented [A351]: REVISE: This response doesn't address the comments. Travel demand models are typically based on individual decision-making, but are not conducted at the individual level; the models instead may, e.g., incorporate demographic variables if they're expected to change over time, as a way to reflect household variation. The comments appear to be about model structure (the simultaneous choice of VMT and vehicle ownership). That modeling can be done at levels of aggregation above the household level. The response should address the decision not to do simultaneous modeling of VMT and vehicle ownership.

(b) Mileage accumulation schedule

To account properly for the average value of consumer and societal costs and benefits associated with vehicle usage under various CAFE and CO_2 alternatives, it is necessary to estimate the portion of these costs and benefits that will occur each calendar year for each model year cohort. Doing so requires some estimate of how many miles the average vehicle of each

[1296] RFF, NHTSA-2018-0067-11789, at 5.
[1297] IPI, Appendix, NHTSA-2018-0067-12213, at 80 (internal citation omitted).

body type is expected to drive at each age. The agencies call these "mileage accumulation schedules." For this final rule, the agencies are modifying the mileage accumulation schedules, largely in response to comments.

(i) Data

As mentioned in previous sections, NHTSA purchased a data set containing 70 million vehicle odometer readings from Polk in part to create the vehicle mileage accumulation schedules used in the NPRM. In the proposal, the agencies explained that Polk data was newer and we believed qualitatively superior to the 2001 and 2009 National Household Travel Survey (NHTS) data used in prior rules.[1298] Consistent with previous analyses,[1299] the agencies used a cross-sectional sample of the Polk data for the NPRM. Cross-sectional data is like a "snapshot" in time. Rather than tracking vehicles over a period, the sample contained a single odometer reading from each vehicle sampled. In other words, the sample contained observations of the total lifetime accumulation of miles (represented by its odometer reading) through CY2015 of all MYs still present on the road. The cross-sectional sample was limited in the number of vintages included in the sample. While the sample was suitable to capture the heaviest usage ages (age zero to 15 years), it contained no observations for vehicles older than 16 years. This required the agencies to rely on mileage accumulation schedules developed from other data sources to produce annual VMT rates for older vehicles. Furthermore, in order to develop a schedule of mileage accumulation by age, it was necessary to assume that each vehicle traveled the same number of miles each year to reach its odometer reading, e.g. if a MY 2007 vehicle had an odometer reading of 88,000 in CY2015, the analysis assumed the vehicle drove 11,000 miles each year from CY2007 to CY2015.

The agencies acknowledged that this approach missed some of the nuances of car ownership.[1300] For example, vehicles are commonly part of multi-vehicle household fleets and their usage changes over time as households buy new vehicles and replace older ones. Similarly, most vehicles belong to multiple owners over the course of their useful lives, each of whom may have different patterns of usage. The most significant limitation of using cross-sectional data is the presence of an attrition bias. As a cohort ages, vehicles that have been used more heavily are more likely to be retired at each age than vehicles that are driven less. As the most heavily-driven vehicles drop out of the fleet, the remaining vehicles, which likely have been driven less at each age throughout their lives, will have lower odometer readings. Making the common, but necessary assumption that each vehicle is driven uniformly at each age results in lower miles-per-age estimates because of this attrition bias. In the schedules used for the NPRM, the effect of this bias occurred during the ages where each model year cohort typically scraps at the highest rates –9 to 15 years. These limitations led to lower estimates, which led commenters such as EDF to state "[g]iven that the Volpe Model VMT falls far short of confident measurements of gasoline consumption, these mileage accumulation schedules need to be increased."[1301] The

[1298] *See, e.g.*, 83 FR at 43089-90 (Aug. 24, 2018).
[1299] Previous rules were based on odometer data from the 2001 National Household Travel Survey (NHTS). S. Lu, "Vehicle Survivability and Travel Mileage Schedules," Report Number: DOT HS 809 952 (January 2006).
[1300] *See* 83 FR at 43092 (Aug. 24, 2018).
[1301] EDF, Appendix B (Rykowski comments), NHTSA-2018-0067-12108, at 46.

agencies note that many of these data limitations were present in previous CAFE ~~and CO2~~ analyses.[1302]

Commented [A352]: CHANGE AS SHOWN: Beginning in the 2016 Draft TAR, NHTSA began using Polk's cross-sectional data, while EPA has continued to use the MOVES VMT schedules which did not include the data anomalies from the limitations referenced in the comments here.

Several commenters noted the agencies' reliance on cross-sectional data, and urged the use of panel data instead to develop mileage accumulation schedules. For example, API argued that cross-sectional data cannot accurately capture mileage accrual and suggested "the agencies re-consider the use of the [Polk] data for developing revised mileage accumulation schedules unless the data can capture mileage accumulation rates versus age on an individual-vehicle basis."[1303] The NPRM discussed the possible use of panel data in the future and the benefits that doing so could provide.[1304]

In response to these comments, the agencies created new mileage accumulation schedules based on panel data for this final rule. Unlike cross-sectional data, panel data includes a temporal element, which resolves the limitations imposed by cross-sectional data. The data source used for the final rule contains sequential readings of individual vehicles over time, and the vehicles are tracked at the VIN level. Polk accumulates readings about individual vehicles through state inspection programs, title changes, and maintenance events, among other sources. The Polk data includes observations of a specific vehicle's odometer readings over the course of many years, capturing the accumulated lifetime mileage at multiple ages. By using the observation date and accumulated miles (represented by the odometer reading), the agencies can compute the rate of driving (miles per year, or month) between observations for each vehicle. This is a superior method to assuming that the rate of accumulation, over all ages, is simply the ratio of odometer to age, as commenters noted. In particular, calculating the rates of mileage accumulation using successive observations of the same vehicle explicitly resolves the attrition bias and matches the approach to estimating driving rates with panel data in other studies.[1305]

The panel dataset has another advantage over other sources: because it tracks individual vehicles over time, we have more precise information about each vehicle's useful age. In previous analyses, the agencies were forced to assume that "age" was simply equal to the calendar year minus the model year in which the vehicle was produced. For example, a MY2010 vehicle was assumed to be five years old in 2015. This created, as API stated, a "discontinuity in the values between year 1 and year 2" within the schedules.[1306] It is common for vehicles produced in a given model year to be sold and registered over the course of multiple calendar years. Thus, a MY2010 vehicle assumed to be five years old in 2015, could have been registered for the first time in CY2012 and might have a real driving age of three years, rather than five, simply because it sat on a dealership lot for a couple of years before being purchased. The Polk data allows us to identify the first registration date of each vehicle in the sample and compute its

[1302] *See, e.g.*, NHTSA Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks, NHTSA-2010-0131, at 372-79.
[1303] API, EPA-HQ-OAR-2018-0283-4548, at 10.
[1304] *See* 83 FR at 43092 (Aug. 24, 2018).
[1305] *See, e.g.*, Kenneth Gillingham, Alan Jenn, and Inês M.L. Azevedo (2015), "Heterogeneity in the Response to Gasoline Prices: Evidence from Pennsylvania and Implications for the Rebound Effect, Energy Economics," Volume 52, Supplement 1, 2015, Pages S41-S52, ISSN 0140-9883, available at https://doi.org/10.1016/j.eneco.2015.08.011.
[1306] API, EPA-HQ-OAR-2018-0283-5458, at 9-10.

true driving age at each point in time. This not only improves the precision of the mileage accumulation rate in the first year, but in subsequent years as well. The odometer data used in the NPRM had another limitation: odometer readings were grouped into cohorts by nameplate, for which only distributional information was available. It was necessary to use the mean odometer reading for each cohort at each age, but in cases where the distribution was skewed, the mean could be misleading. Making the same assumption about registration date, as each cohort contained information about the average registration date, further compounded the potential for distortion.

To the extent that commenters objected to the NPRM's use of Polk data on the basis of it being proprietary, the agencies note that ~~using~~ proprietary data has been used~~is common~~ in some past rulemakings, and, specifically, Polk data has been used for CAFE ~~and CO_2~~ analyses on multiple occasions previously. For the 2016 final medium- and heavy-duty rule ~~and Draft EAR, the agencies~~NHTSA used Polk odometer data to develop the vehicle mileage accumulation schedules.[1307] Further, the specific data set was cited and is available for acquisition through Polk.

Commented [A353]: CHANGE AS SHOWN: In April 2018, EPA proposed the Strengthening Transparency in Regulatory Science rule, which raised questions about using non-public data in regulations. The rule is not yet final. At any rate, even if it's been used in the past, using proprietary data for rules is under question in EPA.

Recently, the 2017 National Household Travel Survey has become available as a possible data source to develop mileage accumulation schedules. While attractive from the standpoint of transparency, ~~it suffers from the same flaws as data sources used to develop previous schedules. In particular,~~ it represents a cross section of odometer readings at a single point in time, requiring the assumption that the rate of usage is simply reported odometer divided by vehicle /age, or an extrapolation of respondents' daily travel behavior into representative annual schedules~~, which commenters suggested was a poor assumption. Additionally, all of the odometers in the newest NHTS are self-reported, leading to questionable reliability of the individual data points (and notably round numbers in many cases).~~ Finally, the NHTS ~~is intended to be a representative sample of *households*, but not a representative sample of *vehicles*. Research has found that creating a *representative* sample of households can represent a significant challenge, as past iterations of the NHTS have systematically oversampled high income households. The nature of the~~ sample also explicitly excludes vehicles used for commercial purposes, which nonetheless compose a meaningful portion of the new vehicle market, accumulate miles of travel, and consume fuel. The data set on which the mileage accumulation schedule used for this final rule is based contains at least two readings (and frequently several) for over 70% of the registered light duty vehicle population in 2016.

Commented [A354]: REVISE: The question being raised here is whether or not the NHTS data is the best source for developing the mileage accumulation schedules. A judgement that there is a better approach does not mean that the NHTS is 'flawed'. Suggest removing this overly-general negative characterization of cross-sectional data.

Commented [A355]: REVISE: The API comments do not make any statement about the approach of extrapolating daily trip data to annual schedules. They only expressed concern about the use of aggregate IHS/Polk panel data, and recommended the use of individual vehicle data (which the NHTS has.) If there is another comment being cited here, the reference should be added.

Commented [A356]: CHANGE AS SHOWN: Suggest removing. The both data sets (Polk/NHTS) use manually collected odometer readings, and the presumption that one is more accurate than the other is not supported here. On the contrary, the Odometer Mileage Record Form used for the NHTS field surveys may be more formalized than, for example, some state DMV vehicle title and registration odometer forms: https://nhts.ornl.gov/assets/2016/NHTS2017_OdometerSheet.pdf

Commented [A357]: CHANGE AS SHOWN: Caution here about this negative characterization of the NHTS. These FHWA data sets include BOTH household and vehicle weighting factors, so it is up to the researcher to apply the appropriate weighting factor for the particular purpose. Suggest removing.

(ii) Methodology

The data used to construct the schedules initially included between two and fifty odometer readings from each of over 251 million unique vehicles. While most of the readings had plausible reading dates, odometer counts, and implied usage rates, some of the readings appeared unrealistic and received additional scrutiny. We used a set of criteria to identify and remove readings that were likely record errors. For example, odometer readings predating the commercial release of the vehicle, showing negative VMT accumulation over time, or taken too

[1307] *See, e.g.*, 81 FR 73478, 73746 (Oct. 25, 2016); *see also* 81 FR 49217 (Jul. 27, 2016).

closely together to provide meaningful insight into annual vehicle usage were removed from the analysis.[1308] Such sanitization of real datasets is typically necessary, and each step in the process was recorded and described in conformity with standard econometric practice.[1309]

Similar to the NPRM, the remaining readings were sorted into five categories: cars, SUV's/vans, pickups, MDHD pickups/vans, and chassis. The car, SUVs/vans and pickup categories match the definitions used to build the VMT schedules used in the NPRM, as well as those used to build the scrappage model. Table VI-116 shows the number of VINs, reading pairs, and average readings per VIN by body style.

Commented [A358]: REVISE: Clarify that this category was not used in the final rule analysis, similar to the footnote on the table below.

Table VI-116 - Summary of Polk/IHS VMT VIN and Reading Data by Body Style

Body Style	Number of VIN's Included	Number of Reading Pairs	Mean Readings per VIN
Car	92,016,334	287,512,165	4.1
SUVs/vans	66,857,117	212,656,710	4.2
Pickups	29,926,984	83,208,986	3.8
MDHD pickups/vans*	10,515,168	27,418,353	3.6
Chassis*	486,471	1,186,653	3.4
Total	199,802,074	611,982,867	4.1

*Not used in this final rule analysis, in part in response to comments.

Once the dataset was cleaned, we created a sample of one million reading pairs, where each pair represented an initial odometer/date reading and a subsequent odometer/date reading from the same vehicle. Analysis of the entire dataset was too computationally demanding and statistically unnecessary. Two conditions were created for sampling. The first controlled for Polk's censoring in the odometer readings recorded in the dataset (described below), and the second ensured the usage data was not biased by survival and that it represented usage rates over a relatively short period of time compatible with the beginning of the FRM analysis. Further analysis suggests that shorter periods between readings is still correlated with higher usage rates so that further filtering of the data sample was considered in the regression analysis. Once these filters were applied, we considered several polynomial fits to the average odometer readings. These fits inform the final usage rates by age and body style used in this FRM analysis. The details are further described below.

Commented [A359]: REVISE: Is the assumption here that shorter periods between readings produce less accurate results than longer periods? What's the basis for that assumption?

One element of the usage data (mentioned above as the first condition control) required the agencies to filter the dataset. The odometer readings recorded are censored at 250k miles.[1310] For this reason, we exclude readings recorded exactly as 250k miles. The censoring could bias estimates of usage rates if odometer readings and future usage rates are correlated, which they

[1308] Refer to Chapter X.XX of the FRIA for a full accounting of the process used to clean the Polk odometer data.
[1309] *See, e.g.*, Osborne, Jason W., Best Practices in Data Cleaning, SAGE Publications, Inc, January 2012.
[1310] Polk codes any vehicle whose odometer exceeds 250K miles as 250K miles exactly, regardless of the actual odometer reading.

likely are. While we hope to reconcile this limitation of the dataset in future work, the benefits of observing actual usage data through 30 years (rather than average odometer readings by model through 15 years) far outweigh the limitation. Still, we filtered out these censored data points, since the actual odometer readings for such vehicles are likely higher than reported.

The Polk dataset is conditional on survival so that it represents the usage of vehicles on the road at the time of the sample (the end of the first quarter of 2017). In this way, it captures the actual observed usage rates of vehicles surviving to their current age in the dataset. An issue with this is that all readings of a vehicle are included in the sample. If usage rates from earlier ages and survival are correlated, which they likely are, then including the readings for a 30-year-old vehicle when it was 10 years old will bias the estimated usage rates of 10-year-old vehicles downward because vehicles that survive to advanced ages tend to be used less than vehicles that are retired at earlier ages for the same model year. As noted above, the NHTS data used in the NPRM suffered from the same problem. To mitigate this issue, we applied a second filter when sampling the data set: we only included readings where the reading date of the second reading in the pair is January 2015 or later. This reduces the potential bias from the joint probability of usage and survival to only those vehicles scrapped between January 2015 and the first quarter of 2017. This balances losing information for older, less represented ages by excluding too much data on these vehicles and severely biasing the estimates of usage by age.

Commented [A360]: **REVISE:** Why is this a bias? Isn't the goal to measure accurately how far 10-year-old vehicles go? If some go for shorter distances, why does it matter, in terms of measuring how far 10-year-old vehicles go, that those vehicles last longer?

For estimates within the CAFE model the average usage is the relevant measure. Table VI-117 - shows the average usage rates for cars by age as well as linear, quadratic, and cubic polynomial fits on these points.[311] The average usage rates follow a relatively smooth pattern, but appear to decline at an accelerating rate for the oldest ages. The linear equation captures this trend for older vehicles, but underestimates early ages. The quadratic fit shows a diminishing decrease in the usage of older vehicles which may overestimate their use. The cubic fit captures the early age usage trends and the accelerating decrease in the usage of older ages. For this reason, we used the cubic curve as the basis for the new VMT schedules by age.

[311] In general, the objective of a polynomial regression is to capture the nonlinear relationship between two variables. While the fit produces a nonlinear curve, it is linear in the coefficients. Choosing the lowest degree of the polynomial function that captures the inflection points in the data preserved degrees of freedom and ensures that applying the polynomial function to observations outside the range of data (as done here for ages beyond 30) is well behaved.

Table VI-117 - Car Averages and Predictions from Polynomial Fits by Age

Age	Averages	Linear	Squared	Cubed
0	16,003	15,072	15,604	**15,922**
1	15,505	14,762	15,188	**15,379**
2	14,259	14,452	14,779	**14,864**
3	14,468	14,142	14,377	**14,378**
4	14,286	13,832	13,983	**13,917**
5	13,676	13,522	13,595	**13,481**
6	13,040	13,212	13,216	**13,068**
7	12,593	12,902	12,843	**12,677**
8	12,278	12,592	12,478	**12,305**
9	11,967	12,282	12,121	**11,952**
10	11,611	11,972	11,770	**11,615**
11	11,167	11,662	11,427	**11,294**
12	10,898	11,352	11,092	**10,986**
13	10,500	11,043	10,763	**10,690**
14	10,297	10,733	10,443	**10,405**
15	10,197	10,423	10,129	**10,129**
16	9,923	10,113	9,823	**9,860**
17	9,715	9,803	9,524	**9,597**
18	9,489	9,493	9,232	**9,338**
19	9,212	9,183	8,948	**9,081**
20	8,786	8,873	8,671	**8,826**
21	8,489	8,563	8,402	**8,570**
22	8,302	8,253	8,139	**8,313**
23	8,366	7,943	7,884	**8,051**
24	7,703	7,633	7,637	**7,785**
25	7,689	7,323	7,397	**7,511**
26	7,073	7,013	7,164	**7,229**
27	6,701	6,703	6,938	**6,938**
28	6,402	6,394	6,720	**6,635**
29	5,965	6,084	6,510	**6,319**
30	6,545	5,774	6,306	**5,988**
31	6,050	5,464	6,110	**5,641**
32	3,295	5,154	5,921	**5,277**
33	NA	4,844	5,740	**4,893**
34	NA	4,534	5,566	**4,488**
35	NA	4,224	5,399	**4,061**
36	NA	3,914	5,240	**3,610**
37	NA	3,604	5,088	**3,133**

38	NA	3,294	4,943	**2,629**
39	NA	2,984	4,805	**2,096**

Table VI-118 - shows the observed and predicted average usage rates by age for SUVs/vans. All the polynomial fits predict the observed average usage rates reasonably well. However, the linear fit under predicts the usage of the oldest vehicles, and the cubic fit predicts higher usage rates for vehicle ages beyond age 30. The quadratic fit predicts reasonable usage rates for all observed and out-of-sample ages through age 40. For this reason, the quadratic fit was used as the basis for the SUV mileage schedule.

Table VI-118 - SUV/Van Averages and Predictions from Polynomial Fits by Age

Age	Averages	Linear	**Squared**	Cubed
0	16,284	15,795	**16,234**	16,042
1	15,802	15,457	**15,805**	15,692
2	14,834	15,119	**15,383**	15,335
3	14,844	14,780	**14,966**	14,971
4	14,871	14,442	**14,557**	14,601
5	14,390	14,104	**14,153**	14,227
6	13,682	13,765	**13,756**	13,850
7	13,240	13,427	**13,366**	13,469
8	12,948	13,088	**12,982**	13,088
9	12,818	12,750	**12,605**	12,706
10	12,443	12,412	**12,234**	12,325
11	12,001	12,073	**11,870**	11,945
12	11,692	11,735	**11,512**	11,568
13	11,258	11,396	**11,161**	11,196
14	10,928	11,058	**10,816**	10,828
15	10,496	10,720	**10,477**	10,466
16	10,160	10,381	**10,146**	10,111
17	9,788	10,043	**9,820**	9,764
18	9,468	9,705	**9,501**	9,426
19	8,897	9,366	**9,189**	9,098
20	8,537	9,028	**8,883**	8,782
21	8,436	8,689	**8,583**	8,478
22	7,993	8,351	**8,290**	8,187
23	8,271	8,013	**8,004**	7,911
24	7,568	7,674	**7,724**	7,650
25	7,325	7,336	**7,450**	7,405
26	7,380	6,997	**7,183**	7,179
27	6,758	6,659	**6,923**	6,970
28	7,123	6,321	**6,669**	6,782
29	6,431	5,982	**6,421**	6,614
30	10,738	5,644	**6,180**	6,467
31	3,958	5,306	**5,946**	6,344
32	NA	4,967	**5,718**	6,245
33	NA	4,629	**5,496**	6,170
34	NA	4,290	**5,281**	6,121
35	NA	3,952	**5,072**	6,100
36	NA	3,614	**4,870**	6,106
37	NA	3,275	**4,674**	6,142

38	NA	2,937	**4,485**	6,207
39	NA	2,598	**4,303**	6,304

Table VI-119 - shows the observed and predicted average usage rates for pickups by age. The observed rates initially decline at an increasing rate, the decline diminishes and appears to accelerate again for the oldest ages. The linear fit underestimates the usage rates for the youngest and oldest ages and overestimates middle-aged vehicles. The quadratic fit reasonably predicts the observed average usage rates but predicts an increase in usage rates for the oldest ages out of the observed sample. The cubic fit reasonably predicts the observed averages and appears to capture the diminishing decline of usage for the oldest ages observed in the in-sample averages. For this reason we used the cubic fit as the basis for the pickup VMT schedules.

Table VI-119 - Pickup Averages and Predictions from Polynomial Fits by Age

Age	Averages	Linear	Squared	**Cubed**
0	18,749	16,377	18,375	**18,964**
1	17,874	16,034	17,633	**17,986**
2	17,213	15,691	16,918	**17,076**
3	16,618	15,348	16,230	**16,231**
4	15,863	15,006	15,570	**15,449**
5	14,911	14,663	14,938	**14,726**
6	13,638	14,320	14,333	**14,060**
7	12,981	13,977	13,756	**13,448**
8	12,662	13,634	13,207	**12,886**
9	12,306	13,291	12,684	**12,372**
10	11,865	12,948	12,190	**11,903**
11	11,433	12,605	11,723	**11,476**
12	11,300	12,262	11,284	**11,088**
13	10,840	11,919	10,872	**10,737**
14	10,503	11,576	10,487	**10,418**
15	10,322	11,233	10,131	**10,131**
16	10,063	10,890	9,802	**9,871**
17	9,661	10,547	9,500	**9,635**
18	9,426	10,204	9,226	**9,421**
19	9,185	9,861	8,979	**9,226**
20	8,744	9,518	8,760	**9,047**
21	8,689	9,175	8,569	**8,882**
22	8,582	8,832	8,405	**8,726**
23	8,634	8,489	8,269	**8,577**
24	8,596	8,146	8,160	**8,433**
25	8,332	7,803	8,079	**8,290**
26	8,430	7,460	8,025	**8,146**
27	8,231	7,117	7,999	**7,998**
28	7,430	6,774	8,000	**7,842**
29	7,315	6,431	8,029	**7,676**
30	7,821	6,088	8,086	**7,497**
31	9,039	5,745	8,170	**7,302**
32	NA	5,402	8,282	**7,089**
33	NA	5,059	8,421	**6,853**
34	NA	4,716	8,588	**6,593**
35	NA	4,374	8,782	**6,305**
36	NA	4,031	9,004	**5,987**
37	NA	3,688	9,254	**5,635**

38	NA	3,345	9,531	**5,248**
39	NA	3,002	9,835	**4,821**

As in the NPRM, the current schedule differs by body-style to represent different usage profiles that we observed in the data. While more stratification is possible, it is unlikely to provide much additional value. Table VI-120 shows the annual miles driven at each age for passenger cars, SUVs (and CUVs and minivans), and pickup trucks at each age of their useful life, conditional upon surviving to that age.

Table VI-120 - Comparison of NPRM and FR mileage accumulation schedules

Age	Cars – NPRM	Cars – FR	SUV – NPRM	SUV – FR	Pickup – NPRM	Pickup – FR
1	17,071	**15,922**	17,276	**16,234**	18,872	**18,964**
2	14,729	**15,379**	15,499	**15,805**	15,950	**17,986**
3	14,611	**14,864**	15,237	**15,383**	15,464	**17,076**
4	14,284	**14,378**	15,091	**14,966**	14,745	**16,231**
5	13,973	**13,917**	14,859	**14,557**	13,734	**15,449**
6	13,549	**13,481**	14,425	**14,153**	12,545	**14,726**
7	12,370	**13,068**	13,611	**13,756**	11,267	**14,060**
8	10,999	**12,677**	12,561	**13,366**	9,879	**13,448**
9	9,514	**12,305**	11,403	**12,982**	8,579	**12,886**
10	8,047	**11,952**	10,162	**12,605**	7,409	**12,372**
11	6,728	**11,615**	8,841	**12,234**	6,394	**11,903**
12	5,650	**11,294**	7,534	**11,870**	6,382	**11,476**
13	5,271	**10,986**	6,319	**11,512**	6,072	**11,088**
14	4,987	**10,690**	5,184	**11,161**	5,839	**10,737**
15	4,940	**10,405**	4,880	**10,816**	5,835	**10,418**
16	4,812	**10,129**	4,733	**10,477**	5,687	**10,131**
17	4,705	**9,860**	4,598	**10,146**	5,534	**9,871**
18	4,611	**9,597**	4,460	**9,820**	5,433	**9,635**
19	4,509	**9,338**	4,333	**9,501**	5,315	**9,421**
20	4,414	**9,081**	4,216	**9,189**	5,195	**9,226**
21	4,322	**8,826**	4,090	**8,883**	5,074	**9,047**
22	4,243	**8,570**	3,991	**8,583**	5,024	**8,882**
23	4,161	**8,313**	3,894	**8,290**	4,920	**8,726**
24	4,080	**8,051**	3,803	**8,004**	4,893	**8,577**
25	4,008	**7,785**	3,723	**7,724**	4,854	**8,433**
26	3,933	**7,511**	3,639	**7,450**	4,750	**8,290**
27	3,887	**7,229**	3,570	**7,183**	4,690	**8,146**
28	3,842	**6,938**	3,520	**6,923**	4,689	**7,998**
29	3,799	**6,635**	3,476	**6,669**	4,757	**7,842**
30	3,764	**6,319**	3,429	**6,421**	4,745	**7,676**
31	3,717	**5,988**	3,395	**6,180**	4,676	**7,497**
32	3,704	**5,641**	3,400	**5,946**	4,702	**7,302**
33	3,714	**5,277**	3,383	**5,718**	4,762	**7,089**
34	3,745	**4,893**	3,392	**5,496**	4,814	**6,853**
35	3,788	**4,488**	3,388	**5,281**	4,960	**6,593**
36	3,769	**4,061**	3,406	**5,072**	4,895	**6,305**
37	3,742	**3,610**	3,394	**4,870**	4,684	**5,987**
38	3,753	**3,133**	3,373	**4,674**	4,776	**5,635**
39	3,760	**2,629**	3,408	**4,485**	4,830	**5,248**
40	3,742	**2,096**	3,385	**4,303**	4,750	**4,821**

(c) Benchmarking total VMT

In order to assess the fuel consumption and environmental impacts of regulatory alternatives, it is desirable to have a representation of aggregate travel and fuel consumption that is both reasonable and internally consistent. Some commenters suggested that the aggregate totals presented in the NPRM deviated from other published estimates, and argued that the entire analysis was therefore an unreliable source of information for decision-makers to consider. For example, EDF stated, "the NHTSA model 'projects' aggregate, nationwide VMT levels for 2016 and 2017 that are about 20 percent lower than formal government estimates by EIA and FHWA."[1312] EDF further stated, "[b]etween 2017 and 2025, fleetwide VMT grows by 3.1% per year in the Volpe Model, while it only grows 0.5% per year in the 2018 Annual Energy Outlook."[1313] EDF also suggested, "[o]ne obvious way to assess the accuracy of the schedules is to compare the projections of the Volpe Model of total fleetwide fuel consumption in a recent calendar year with actual gasoline sales."[1314]

The Federal Highway Administration (FHWA) publishes annual VMT estimates for the light-duty vehicle fleet, the most recent of which is calendar year 2017. The NPRM estimate of total light-duty VMT was 2.22 trillion miles in calendar year 2016. The FHWA estimate for light duty VMT in 2016 was 2.85 trillion miles.[1315] While the definitions of light-duty are not identical in the two cases (where FHWA excludes trucks with 10,000 lbs. GVW, the agencies' analysis excludes trucks with GVW greater than 8,500 lbs. from its light duty definition), that definitional discrepancy is not significant enough to account for the difference in the total VMT. While some commenters suggested that we compare simulated fuel consumption to published estimates from EIA to determine the validity of our VMT assumptions, such a comparison requires accurate assumptions about the true on-road fuel efficiency of registered vehicles over forty model years in addition to their annual usage. Comparing simulated VMT directly to FHWA measurements requires fewer assumptions and is a more meaningful comparison.

Substituting the updated mileage accumulation schedules for the NPRM schedules, and using the calendar year 2016 fleet from the NPRM, produces an estimate of total light duty VMT in 2016 that is about 2.85 trillion miles – nearly identical to the FHWA estimate for 2016, despite the use of different estimation methods and data sources. FHWA's estimate of total light-duty VMT in 2017 is 2.88 trillion miles,[1316] while the estimate produced by the simple product of the mileage accumulation schedule on the estimated on-road fleet is 2.94 trillion miles, a difference of about two percent. While not as close as the estimate for calendar year 2016, the discrepancy is still small considering that the estimates are obtained through entirely different methods. One important source of discrepancy with FHWA's 2017 VMT estimate is the fact that the CAFE model simulation assumes all of the vehicles produced in a given model year are driven for the entire calendar year matching the vintage[1317]. This means, for calendar

[1312] EDF, Appendix A, NHTSA-2018-0067-12108, at 59.
[1313] EDF, Appendix B (Rykowski comments), NHTSA-2018-0067-12108, at 44.
[1314] *Id.* at 43.
[1315] *See* Highway Statistics 2017, Table VM-1, available at https://www.fhwa.dot.gov/policyinformation/statistics/2017/vm1.cfm.
[1316] *Id.*
[1317] The CAFE model uses an annual timestep, meaning that each time period represents one year. Because calendar years are (obviously) years, and all of the other inputs (discounting and inflation, macroeconomic variables, fuel

year 2017, the initial year of the simulation used to support this rule, MY2017 vehicles are assumed to have been both registered and driven for the entirety of CY2017. As a result, it naturally overestimates the true VMT for calendar year 2017. The analysis accounts for this discrepancy by adjusting calendar 2017 total VMT downward by one percent, and the discrepancy in total VMT caused by conflating model years and calendar years dissipates over time.

While we have established that the years for which we have data are sufficiently similar to published VMT estimates, the question of projection still remains. FHWA, in its forecasts of VMT (Spring 2019),[1318] forecasts a compound annual growth rate of 0.8% for light-duty vehicles between 2017 and 2047 in its baseline economic outlook. However, that projection uses a different set of macroeconomic conditions and fleet assumptions than this analysis. To compare CAFE model simulations of total VMT to the FHWA projections, we ran the FHWA model with a comparable set of assumptions to the greatest extent possible.[1319][1320] Using similar economic growth assumptions, our reference case total light-duty VMT grows at a compound rate of 0.63 percent per year between 2017 and 2050. Using comparable assumptions in the FHWA model produce an annual growth rate of 0.66 percent. Again, these differences are remarkably low for models created with different methods, and lead to trivial variances, for the purposes of our analysis, in total VMT. The relevant annual projections for the baseline scenario appear in Table VI-121 -.

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prices, VMT, etc.) represent annual values, the timestep in the CAFE model is a calendar year. However, model years start prior to the calendar year for which they are named, and new model year sales continue (albeit only slightly) after their calendar year ends. In order to account for model year sales on their true timing relative to calendar years, the model would need to be restructured to use a quarterly timestep. While this would improve the fidelity between calendar year and model year for sales, obtaining quarterly projections of nearly every other variable in the analysis would be complicated (if not impossible). For this reason, the model conflates "model year" and "calendar year" for the analysis, even though it is a simplification.

[1318] *See* "FHWA Forecasts of Vehicle Miles Traveled (VMT): Spring 2019," Office of Highway Policy Information, available at https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_forecast_sum.pdf.

[1319] *See* "FHWA Travel Analysis Framework: Development of VMT Forecasting Models for Use by the Federal Highway Administration," Volpe, available at https://www.fhwa.dot.gov/policyinformation/tables/vmt/vmt_model_dev.pdf.

[1320] In particular, we ran the FHWA VMT forecasting model with the same: personal disposable income, population, fuel prices (all of which come from AEO2019), and simulated on-road fleet fuel economy in the baseline.

Table VI-121 - Comparing projections of total light-duty VMT

Year	FHWA Projection (Trillion VMT)	CAFE Model Projection (Trillion VMT)	Percent Difference
2017	2.88	2.91	1.1
2018	2.97	2.98	0.5
2019	3.05	3.05	0.1
2020	3.10	3.10	0.0
2021	3.13	3.13	0.1
2022	3.17	3.18	0.2
2023	3.21	3.22	0.3
2024	3.25	3.26	0.4
2025	3.28	3.29	0.5
2026	3.30	3.33	0.7
2027	3.33	3.36	0.8
2028	3.35	3.38	1.0
2029	3.37	3.41	1.2
2030	3.39	3.43	1.2
2031	3.41	3.45	1.3
2032	3.43	3.48	1.2
2033	3.46	3.50	1.2
2034	3.47	3.51	1.1
2035	3.49	3.53	1.0
2036	3.51	3.54	0.9
2037	3.52	3.55	0.7
2038	3.53	3.56	0.6
2039	3.54	3.56	0.5
2040	3.55	3.56	0.4
2041	3.55	3.56	0.2
2042	3.56	3.56	0.1
2043	3.56	3.56	(0.0)
2044	3.56	3.56	(0.2)
2045	3.57	3.55	(0.3)
2046	3.57	3.55	(0.5)
2047	3.56	3.54	(0.6)
2048	3.56	3.54	(0.7)
2049	3.56	3.53	(0.8)
2050	3.56	3.53	(1.0)

(d) Preserving total VMT across regulatory alternatives

In the NPRM, the combined effect of the sales and scrappage responses created small percentage differences in total VMT across the range of regulatory alternatives.[1321] However, as the Environmental Group Coalition noted, even a 0.4 percent difference can result in "692 billion additional VMT under the CAFE standards and 894 billion under the CO2 program."[1322] Since VMT is related to many of the costs and benefits of the program, VMT of this magnitude can have meaningful impacts on the incremental net benefit analysis. This point was made by a number of commenters who were concerned about the magnitude and direction of differences in VMT between regulatory alternatives (IPI, EDF, CBD, CARB).[1323]

More generally, commenters argued that non-rebound VMT should be held constant across regulatory alternatives, regardless of the number of new vehicles sold and registered vehicles scrapped. For example, CBD commented that the "total number of VMT should be determined based on demand for travel, not arbitrarily driven by fleet size." CARB added that fleet size can change across the alternatives "as long as the VMT schedules are adjusted to account for overall travel activity that is distributed over a larger number of vehicles." [1324] NCAT, Global, Auto Alliance, EDF, IPI, and Honda made similar arguments.[1325]

While commenters generally provided few specific recommendations about the level to which VMT should be constrained among alternatives, several of them argued that VMT projections would benefit from consideration of travel demand modeling. UCS, CBD, NCAT, and others suggested that the overall level of light-duty VMT in a given year should reflect the broader economic context in which travel occurs.[1326] For example, Honda stated, "[i]ncreasing VMT is closely associated with increased economic activity."[1327]

The agencies agree that the total demand for VMT should not vary excessively across alternatives ~~and stated as much in the NPRM~~.[1328] That said, it is reasonable to assume that fleets with differing age distributions and inherent cost of operation will have slightly different annual VMT, absent VMT associated with rebound miles; however, the difference could conceivably be small. To address these comments ~~and to take an intentionally conservative approach~~, the agencies decided to constrain "non-rebound" VMT (defined more explicitly below) to be identical across regulatory alternatives in this analysis using the FHWA VMT demand model to

Commented [A361]: DELETE: The cited NPRM section (83 FR 43099) does not contain a mention of the importance of maintaining non-rebound VMT across alternatives. On the contrary, the cited text says "the total non-rebound VMT for CY 2050 is 0.4% larger in the augural baseline than in the proposed standards. This small increase in VMT is consistent with a larger fleet size; if more used vehicles are supplied, there likely is some small resulting increase in VMT."

Commented [A362]: CHANGE AS SHOWN: "conservative" is ambiguous here. Following from the previous sentence, a fully comprehensive approach would have somewhat lower non-rebound VMT under more stringent standards, since vehicles are older and presumably have lower utility (see Honda comments.)

The approach that was used for the FRM to hold non-rebound VMT constant was simpler, but not necessarily more "conservative." Suggest either removing this statement, or add additional explanation.

[1321] The agencies explained in the NPRM that some amount of this difference was due to the rebound effect, and that "non-rebound" VMT between alternatives differed by as much as 0.4%. *See* 83 FR at 43099 (Aug. 24, 2018).
[1322] Environmental Group Coalition, Appendix A, NHTSA-2018-0067-12000, at 180.
[1323] *See, e.g., Id.*; EDF, Appendix B (Rykowski comments), NHTSA-2018-0067-12108, at 42-46; IPI, Appendix, NHTSA-2018-0067-12213; at 79; CARB, Detailed Comments, NHTSA-2018-0067-11873, at 237-242.
[1324] CARB, Detailed Comments, NHTSA-2018-0067-11873, at 238 (internal citation omitted).
[1325] *See, e.g.*, Global, Attachment A, NHTSA-2018-0067-12032, at A-26-A-30; NCAT, Comments, NHTSA-2018-0067-11969, at 28-32; EDF, Appendix A, NHTSA-2018-0067-12108, at 30; IPI, Appendix, NHTSA-2018-0067-12213, at 80-85; Honda, NHTSA-2018-0067-12111.
[1326] *See, e.g.*, NCAT, Comments, NHTSA-2018-0067-11969, at 31-32; Environmental Group Coalition, Appendix A, NHTSA-2018-0067-12000, at 175-76. UCS, Technical Appendix, NHTSA-2018-0067-12039, at [xxx].
[1327] Honda, Supplemental Analysis, NHTSA-2018-0067-1211, at 4.
[1328] *See* 83 FR at 43099 (Aug. 24, 2018).

determine the constraint; therefore, the only difference in total VMT between regulatory alternatives is the rebound miles attributable to differences in fuel economy resulting from the regulatory alternatives. ~~Nevertheless, as explained in the NPRM and revealed in the extensive quantitative results published with the NPRM, setting aside the rebound effect, aggregate VMT as estimated in the NPRM was roughly constant across alternatives. Although differences may have appeared large in absolute terms, especially when aggregated across many calendar years and ignoring the underlying annual total quantities, the differences were nevertheless very small in relative terms—small enough to be well within the range of measurement or estimation error for virtually any of the other inputs to, or outputs of, the agencies' analysis. It is unclear whether a 0.4 percent change in highway travel can be measured with any degree of confidence.~~

Commented [A363]: DELETE: While at first glance it may sound reasonable that 0.4 percent is small and therefore not significant, in many cases our ability to estimate small incremental differences does not rely on our ability to measure absolute values very precisely. This is frequently the case when overall populations or activity are projected into the future.

To give a specific example here, the accelerated scrappage lowers the average age of vehicles by 0.05 years (0.5%), and the new sales are increased by 2.2M (1.0%). The age, in particular, would be hard to measure that precisely in absolute terms, but that uncertainty does not necessarily affect the incremental estimate.

Suggest removing, since it is contradictory to similar small incremental differences used throughout the analysis.

To constrain non-rebound VMT, the agencies needed to create a definition of non-rebound VMT and a method for calculating it. The agencies used the FHWA VMT forecasting model to produce a forecast of non-rebound VMT, to which total non-rebound VMT in every regulatory alternative is constrained in each year, regardless of the fleet size or distribution of ages in the fleet. In calendar years where total non-rebound VMT determined by the size of the fleet and assumed usage of each vehicle is lower than the constraint produced from the FHWA model, VMT is added to that total and allocated across vehicles to match the non-rebound forecast (preserving the constraint). These additional miles are then carried throughout the analysis as vehicles accrue costs and benefits. Because non-rebound VMT is being held constant for the FRM analysis across the set of regulatory alternatives in each calendar year, the only difference in VMT among the alternatives in any calendar year results from differences in fuel economy improvement relative to MY2016 that occur as a result of the standards (that is, the rebound effect). Finally, in subsection (D), the agencies calculate the changes in total VMT attributable to fuel economy, otherwise known as the rebound VMT.

Commented [A364]: REVISE: Would this occur if the fleet size is too small to produce the VMT using the fleet schedule? That is, to be clear, the gap occurs when the sum of VMT/vehicle by vintage multiplied by the number of vehicles in each vintage is less than the constraint – yes? And the applied correction is entirely to the VMT/vehicle by vintage rather than adjusting the number of vehicles by year? It may help to spell that out explicitly.

(i) Defining non-rebound VMT

In order to constrain non-rebound VMT, it is first necessary to define "non-rebound VMT" more precisely. The NPRM defined the rebound effect as the overall elasticity of travel with respect to changes in the cost per mile (CPM). CPM has two components. The first component of CPM is fuel prices—we expect vehicles to be driven less if fuel prices go up, all else equal. The second component of CPM is fuel economy. Therefore, the NPRM defined the percentage change in CPM, for a given scenario, model year, and calendar year, as:[1329]

Equation VI-6 - Full change in cost-per-mile of travel

$$\%\Delta CPM_{SN,MY,CY} = \frac{\left(\frac{FP_{CY}}{FE_{SN,MY}} - \frac{FP_{2016}}{FE_{REF}}\right)}{\frac{FP_{2016}}{FE_{REF}}}$$

Where *FP* is fuel price, *FE* is fuel economy, and *REF* refers to the reference FE value of a given age (in particular, $FE_{2016-(CY-MY)}$, which is the FE of the MY cohort that was age CY –

[1329] *See* 83 FR at 43091 (Aug. 24, 2018).

MY in CY 2016). In the equation above, $FE_{SN,MY,CY}$ refers to the observed fuel economy of the MY cohort (typically applied at the vehicle level) for a given scenario (SN) in calendar year CY.

The CAFE model uses one value, the value specified as the rebound effect, to measure CPM elasticity. ~~Naturally, t~~The CAFE model produces the same magnitude of change in travel for equivalent changes in fuel prices and fuel economy. Constructing such a projection of future VMT (from 2017 to 2050) that sets aside the rebound effect required constructing inputs that were consistent with that perspective. In particular, it was necessary to separate the price response associated with the change in fuel prices relative to the year on which we based the mileage accumulation schedule (end of CY2016), and the change in VMT associated with only the improvements in fuel economy, relative to MY2016, that occur for future model years at the forecasted fuel price.

Commented [A365]: CHANGE AS SHOWN: That's mathematically true, but various researchers may debate whether it's a reasonable assumption.

As vehicles age, we expect their VMT to decrease in the presence of a non-zero rebound effect if rising fuel prices over time increase their per-mile cost of travel, and the rebound effect represents the degree to which their travel is reduced for a percentage change increase in operating cost. It is intuitive that, as the cost of fuel rises over time, a vehicle with a fixed fuel economy would be driven less if gasoline costs $3.50/gallon than it would be if gasoline costs $2.50/gallon. Such a response is also consistent with economic principles (and literature),[1330] and so it is included in the "non-rebound" VMT that we constrain across alternatives in each calendar year.

Similarly, the annual mileage accumulation of cohorts in the inherited fleet is clearly affected by fuel price, but also by evolution. Setting aside any fuel economy improvements in vehicles sold and entering the on-road fleet between 2017 and 2050, the average fuel economy of each age cohort is going to improve over that period. The travel behavior of the on-road fleet was last observed through calendar year 2016 in the Polk data (discussed in (b)(ii)), when a 20-year-old car was part of the model year 1997 cohort, and had an average fuel economy of 23.4 MPG. However, the fleet continually turns over. In 2035, the 20-year-old car will be a member of the model year 2016 cohort, and have an average fuel economy of 29.2 MPG (assumed to be the average fuel economy of MY2016 vehicles when they were new).[1331] If fuel prices persist at 2016 levels (in real dollars), then that 25 percent improvement in fuel economy would reduce the cost per mile of travel for 20-year-old vehicles relative to the observed values in calendar year 2016, and lead to an increase in travel demand for vehicles of that age. Importantly, this transition to more efficient age cohorts occurs in all of the regulatory alternatives. Considering only the fuel economy levels of vehicles that exist prior to the first year of simulation (2017), a secular improvement in the fuel economy of the on-road fleet would occur with no further

[1330] *See, e.g.*,Goodwin, P., J. Dargay, and M. Hanly. Elasticities of road traffic and fuel consumption with respect to price and income: a review. Transport Reviews, 24:275-292, 2004.

[1331] In practice, vehicles will scrap at different rates over time, even within a body-style. Some nameplates and manufacturers have reputations for longevity and individual vehicle models with different fuel economies may seem like better candidates for repairs under particular fuel price scenarios. In light of this, the fuel economy for a given body-style will likely not continue to be the sales-weighted average fuel economy when the cohort was new, even without accounting for degradation and changes to the on-road gap over time. We make this assumption here out of necessity.

improvements in fuel economy from new vehicles in model years 2017 to 2050. As the fleet turns over, its fuel efficiency will gradually resemble that of the model year 2016 cohort, up to the point at which each age cohort is as efficient as the model year 2016 cohort.[1332]

The notion of "non-rebound" VMT is a construct necessary to support this regulatory analysis by controlling for VMT attributable to reasons other than rebound driving, but present only in theory. Using our symmetrical definition of rebound to represent the expected response to changes in CPM, regardless of whether those changes occur as a result of changes in fuel price or fuel economy, it is well established that demand for VMT responds to the cost of travel. To isolate the change in VMT for which the regulatory alternatives are responsible, we have also included the VMT attributable to secular fleet turnover (through MY2016) in the total "non-rebound" VMT projection. In particular, this means that the conventional rebound definition used in previous analyses, is replaced in the "non-rebound" VMT estimation with a more limited definition:

Equation VI-7 - Fuel price and secular improvement component of elasticity

$$\%\Delta\mathbf{NonRbdCPM}_{MY,CY} = \frac{\left(\frac{FP_{CY}}{FE_{MIN(2016,MY)}} - \frac{FP_{2016}}{FE_{REF}}\right)}{\frac{FP_{2016}}{FE_{REF}}}$$

Where *FP* is fuel price, *FE* is fuel economy, and *REF* refers to the reference FE value of a given age (in particular, $FE_{REF} = FE_{2016-(CY-MY)}$, which is the average FE of the MY cohort that was age (CY – MY) in CY 2016). In Equation VI-7, $FE_{MIN(2016,MY)}$ refers to the observed fuel economy of the model year being evaluated up to and including the 2016MY cohort. This construction explicitly accounts for the improvement in fuel economy between MY2016 and all the historical ages (through MY1977) with respect to the change in (real) fuel price relative to calendar year 2016. Thus, the VMT associated with the rebound effect in this analysis only accounts for changes to CPM that result from the amount of fuel economy improvement that occurs relative to MY2016. The full elasticity definition (in Equation VI-6) differs from that in Equation VI-7 in only one way; the fuel economy in the denominator of the first term is the fuel economy of the model year being evaluated, rather than being the minimum of the actual model year and model year 2016.

Combining this demand elasticity with the endogenously estimated vehicle population and the mileage accumulation schedule provides an initial estimate of non-rebound VMT, as in Equation VI-8.

[1332] Vehicles scrap at different rates over time, and there are important differences by body style for both scrappage rates and mileage accumulation. This discussion is intended to provide intuition, without all of the computational nuance that exists in the model's implementation.

Equation VI-8 - Unadjusted total non-rebound VMT in a calendar year

$$NonReboundVMT = \sum_{A}^{Ages} \sum_{S}^{Styles} VMT_{A,S} \cdot (1 + \%\Delta NonRbdCPM_{MY,CY} \cdot \varepsilon) \cdot Population_{CY,A,S}$$

In Equation VI-8, *VMT* represents the non-rebound mileage accumulation schedule (by age, *A*, and body style, *S*), *Population* is the on-road vehicle population simulated by the CAFE Model (in calendar year *CY*, for each age, *A*, and body style, *S*), ε is the elasticity of demand for travel (the rebound effect, assumed to be -0.2 in this analysis).

However, there are factors beyond the CPM that affect light-duty demand for VMT. The FHWA VMT forecasting model includes additional parameters that can mitigate or increase the magnitude of the effect of fuel price changes on demand for VMT. In particular, the model accounts for changes to per-capita personal disposable income (and U.S. population) over time. This means that even if fuel prices are increasing over the study period (as they are in the central case), and fleetwide fuel economy improves only through fleet turnover (as it does in the simulated "non-rebound" case), total demand for VMT can still grow as a result of increases in these other relevant factors. Not only does the forecast of non-rebound VMT continue to grow in the non-rebound case, it does so at a faster rate than Equation VI-8 produces. Thus, in order to preserve non-rebound VMT in a way that represents expected VMT demand, we must constrain non-rebound VMT in each alternative to match the forecast produced by the FHWA model using the fuel price series from the central analysis, AEO2019 reference assumptions for per-capita personal disposable income, and fleetwide fuel economy values produced by simulating the effect of fleet turnover (only) in the CAFE model.[1333]

(ii) Constraining non-rebound VMT

For this final rule, total "non-rebound" VMT is calculated for each calendar year, based on the initial starting point described above in Section (c) and a series of growth rates calculated from a forecast produced by running central analysis values through the FHWA light-duty VMT forecasting model. In any future calendar year, "non-rebound" VMT is calculated as a product of the initial CY2017 total and a series of compound growth rates:

Equation VI-9 - Total non-rebound VMT constraint in each calendar year

$$\prod_{2017}^{CY} (1 + r_{CY}) \cdot TotalVMT_{2017}$$

Where *CY* is calendar year, *r* is the compound annual growth rate (unique to each CY), and *TotalVMT* is the calendar year total light-duty VMT estimated by the CAFE Model using the annual VMT for each body style and age in the mileage accumulation schedule (defined in Table VI-120), the population of each age/style cohort in CY2017, and the initial difference between operating costs in 2016 and 2017. The compound annual growth rates, r_{CY}, in Equation VI-9 are

[1333] [Text Forthcoming]

derived from the inter-annual differences in the forecast of total non-rebound VMT that we created using the FHWA model.

We used the FHWA forecasting model to produce two distinct VMT forecasts (both of which appear in Table VI-122 -). The first of these is identical to the forecast of total VMT reported in Table VI-121 -, and represents the AEO2019 reference case assumptions with the exception of average on-road fuel economy, which was simulated using the CAFE model to simulate new vehicle fuel economy, new vehicle sales, and vehicle retirement under the baseline standards. The forecast in the second column of Table VI-122 - is identical to the first, except that the average on-road fuel economy accounts for only the effect of fleet turnover on fuel economy improvements (new vehicles are assumed to be only as fuel efficient as the MY2016 cohort, discussed above).

Table VI-122 - VMT projections (trillion miles)

Year	Total VMT (FHWA model)	Non-rebound VMT (FHWA model)	Non-rebound VMT constraint (CAFE Model)	Non-rebound VMT endogenous (CAFE Model)
2017	2.88	2.88	2.91	2.93
2018	2.97	2.97	2.97	2.91
2019	3.05	3.04	3.03	2.95
2020	3.10	3.09	3.07	2.95
2021	3.13	3.12	3.09	2.97
2022	3.17	3.16	3.12	3.00
2023	3.21	3.19	3.14	3.01
2024	3.25	3.22	3.16	3.02
2025	3.28	3.25	3.18	3.03
2026	3.30	3.27	3.20	3.04
2027	3.33	3.28	3.21	3.04
2028	3.35	3.29	3.22	3.04
2029	3.37	3.30	3.22	3.04
2030	3.39	3.32	3.23	3.05
2031	3.41	3.33	3.24	3.05
2032	3.43	3.35	3.25	3.05
2033	3.46	3.36	3.26	3.05
2034	3.47	3.37	3.27	3.05
2035	3.49	3.38	3.28	3.05
2036	3.51	3.39	3.28	3.05
2037	3.52	3.39	3.29	3.05
2038	3.53	3.40	3.29	3.05
2039	3.54	3.40	3.29	3.04
2040	3.55	3.40	3.29	3.04
2041	3.55	3.40	3.29	3.03
2042	3.56	3.40	3.29	3.03
2043	3.56	3.39	3.29	3.02
2044	3.56	3.39	3.29	3.02
2045	3.57	3.39	3.29	3.01
2046	3.57	3.38	3.28	3.01
2047	3.56	3.38	3.28	3.00
2048	3.56	3.37	3.27	3.00
2049	3.56	3.37	3.27	2.99
2050	3.56	3.36	3.27	2.99

The third column is the non-rebound VMT constraint produced by the CAFE model, to which non-rebound VMT is constrained to in every regulatory alternative (under central analysis assumptions regarding fuel prices and economic growth). The non-rebound VMT constraint is produced endogenously by the model in each run based on the estimated VMT for calendar year 2017 and a series of growth rates intended to reproduce the general growth trend in light-duty VMT under the set of "non-rebound" assumptions in the FHWA model (Equation VI-9 -).[1334] It differs from the "non-rebound" forecast produced by the FHWA model by one to three percent in any year. This adjustment was both an attempt to match the FHWA model's projection of total VMT (including rebound) in the baseline, and an acknowledgment that differing levels of modeling resolution and construction are likely to produce slightly different projections. In general, the one to three percent difference in non-rebound VMT is within the range of projections based on the confidence intervals of the coefficients that define the FHWA forecasting model.

The fourth column in Table VI-122 - represents the unadjusted "non-rebound" VMT produced by the CAFE Model using Equation VI-8. The reader will observe that in every calendar year, this total is lower than the non-rebound VMT constraint. This occurs because the projected fuel prices in the central analysis increase much faster than the fleetwide fuel economy (in the non-rebound case). This increases CPM and, as a consequence, reduces demand for VMT based on the price elasticity of demand for travel (rebound effect). However, the FHWA model accounts for additional variables that recognize the economic context in which this fuel price projection occurs. In particular, the model accounts for changes in the U.S. (human) population and changes to personal disposable income over the same period. These factors act to attenuate the demand response to rising fuel prices, producing a rising demand for VMT even as the CPM rises for several years.

In order to constrain non-rebound VMT to be identical in each year across regulatory alternatives, it is necessary to add VMT to the unadjusted total, endogenously calculated by the CAFE Model in each calendar year. These additional miles, denoted Δmiles for this discussion, represent the simple difference between the annual VMT constraint (column 3 of Table VI-122 -) and the unadjusted VMT defined in Equation VI-8(above) in each calendar year.

Equation VI-10 - Difference between VMT constraint and unadjusted non-rebound VMT

$$\Delta Miles_{CY} = VMTConstraint_{CY} - NonReboundVMT_{CY}$$

Because each regulatory scenario produces a unique on-road fleet (in terms of the number of vehicles, the distribution of ages among them, and the resulting distribution of fuel economies), the total unadjusted VMT in each calendar year (given by Equation VI-8 -) will be unique to each regulatory scenario. As a corollary, $\Delta miles_{cy}$ will also be unique to each regulatory scenario. By distributing $\Delta miles_{cy}$ across the vehicle fleet in each calendar year, the CAFE Model scales up the unadjusted non-rebound VMT to equal the non-rebound VMT constraint in each calendar year, for each regulatory alternative. While there are a number of

[1334] This ensures internal consistency with the set of assumptions provided by the user, but can lead to differences between the non-rebound VMT constraint in the central analysis and one that is generated under a different set of assumptions (as in the sensitivity analysis, for example).

ways to reallocate $\Delta miles_{CY}$ across the on-road fleet in order to match the non-rebound VMT constraint, the fact that unadjusted VMT is always lower suggests an obvious approach.

The primary goal of reallocation is to adjust total non-rebound VMT so that it is identically equal to the VMT constraint in every calendar year for each regulatory alternative, while conserving the general trends of the mileage accumulation schedule – which represents a good estimate of observed usage at the start of the simulation. In particular, the reallocation approach should preserve the basic ideas that annual mileage decreases with vehicle age because newer (and more efficient) vehicles are more likely to be driven additional miles than their older counterparts, and mileage accumulation varies by body style. To accomplish the reallocation, the CAFE Model computes a ratio that varies by body style, calendar year, and regulatory alternative. The ratio captures the share of additional VMT that can be absorbed by the registered vehicle population of each body style based on their relative representation in the fleet, so that per-vehicle totals across ages remain sensible (even if the distribution of body styles should change over time as the new vehicle market evolves). Then this quantity is further scaled by the total VMT for a given body style in the calendar year for which $\Delta miles$ has been computed. The resulting ratio is then used to scale the unadjusted miles from Equation VI-8, so that the new sum of annual (non-rebound) VMT across all of the vehicles in the on-road fleet equals the constraint. For a single calendar year, *CY*, and a single body style, *S*, the scaling ratio, *R*, is computed as:

Equation VI-11 - Calculating the scaling factor to reallocate non-rebound VMT

$$R_{S,CY} = \frac{\Delta Miles_{CY} \cdot \frac{\sum_0^{39} Population_{S,A}}{\sum_S^{Styles} \sum_0^{39} Population_{S,A}}}{NonReboundVMT_{CY}}$$

In Equation VI-11, *Population*, refers to the on-road vehicle population for a given age and body style (summed over the full range of ages in the simulation, where vehicles are modeled to survive for, at most, forty years). The fraction in the numerator calculates the fleet composition by body type.[1335] As long as the unadjusted non-rebound VMT produced by the CAFE Model is smaller than the VMT constraint for all years and regulatory alternatives (and it is), this scaling ratio allows the CAFE Model to add miles to the annual total in a way that preserves the basic ideas of the mileage accumulation schedule and achieves equality with the constraint. In particular, the total *adjusted* non-rebound VMT is then calculated as:

[1335] We also considered basing this ratio on each body style's share of total VMT in that calendar year. However, that approach has the potential to result in allocations that add (or remove) too many miles per vehicle, depending on the age distribution and size of each body style cohort. While that approach better preserves the age distribution of VMT within a style, capturing the differences in age distribution of the population in each scenario is an objective of the VMT accounting. In testing, the differences in approach were small (about 0.1% difference).

Equation VI-12 - Total adjusted VMT that preserves non-rebound VMT constraint

$$AdjNonRbdVMT = \sum_{A}^{Ages} \sum_{S}^{Styles} NonReboundVMT_{CY,A,S} * \left(1 + R_{S,CY}\right)$$

To make each alternative match the VMT constraint, Equation VI-12 allocates miles (in this case, adds) to each vehicle in a calendar year by multiplying the product of the mileage accumulation schedule (for that style vehicle, at that age), the %ΔNrbdCPM (described in Equation VI-7), and the elasticity (the rebound effect of -0.2) with the appropriate scaling ratio (defined in Equation VI-11). The "Allocated Miles" in Table VI-116 are the result of this calculation for a passenger car in CY2020.

Unlike some of the accounting, which focuses on the impacts to a model year cohort of vehicles over the course of its useful life, the rebound constraint and reallocation are calendar year concepts. The constraint represents demand for VMT absent "rebound miles" (defined more explicitly above) in a specific calendar year. Thus, this reallocation occurs in every calendar year, and a vehicle of a model year cohort will likely experience many of these reallocation events during its simulated useful life. The resulting survival weighted mileage accumulation is discussed in detail in the discussion of VMT resulting from simulation found in Section (e), but an example of the annual reallocation is provided here.

In the baseline alternative, the non-rebound VMT constraint in CY2020 is about 3.068T miles, but the endogenously computed "non-rebound" VMT is only 2.955T miles. This creates a difference, $\Delta miles_{2020}$, of 112.6B miles that must be added to the total unadjusted non-rebound VMT in calendar year 2020 and allocated across the on-road fleet in that year to preserve total non-rebound VMT. Over time, this discrepancy between the FHWA model's projection and the unadjusted total non-rebound VMT grows to about 230 billion miles. While the other classes operate identically, this example uses the reallocation that occurs to passenger cars to illustrate the mechanics of reallocation. Rising fuel prices depressing non-rebound VMT (relative to the mileage schedule) over time is a general trend that emerges for all body styles, as shown for passenger cars in Table VI-123 -.

Table VI-123 - CY2020 passenger car VMT reallocation to preserve non-rebound constraint

Age	Model Year	Unadjusted Non-Rebound VMT	Allocated	Adjusted Non-Rebound VMT	Vehicle Mileage Accumulation Schedule (Table VI-119)
0	2020	14,958	590	15,548	15,922
1	2019	14,479	571	15,050	15,379
2	2018	14,077	555	14,632	14,864
3	2017	13,615	537	14,152	14,378
4	2016	13,275	524	13,798	13,917
5	2015	13,046	515	13,561	13,481
6	2014	12,538	495	13,033	13,068
7	2013	12,259	484	12,742	12,677
8	2012	11,943	471	12,414	12,305
9	2011	11,431	451	11,882	11,952
10	2010	11,239	443	11,682	11,615
11	2009	10,821	427	11,248	11,294
12	2008	10,451	412	10,863	10,986
13	2007	10,135	400	10,535	10,690
14	2006	9,797	386	10,183	10,405
15	2005	9,563	377	9,940	10,129
16	2004	9,285	366	9,651	9,860
17	2003	9,042	357	9,399	9,597
18	2002	8,740	345	9,085	9,338
19	2001	8,495	335	8,830	9,081
20	2000	8,244	325	8,569	8,826
21	1999	8,003	316	8,319	8,570
22	1998	7,813	308	8,121	8,313
23	1997	7,551	298	7,849	8,051
24	1996	7,332	289	7,621	7,785
25	1995	7,053	278	7,331	7,511
26	1994	6,782	267	7,049	7,229
27	1993	6,494	256	6,750	6,938
28	1992	6,148	242	6,391	6,635
29	1991	5,906	233	6,139	6,319
30	1990	5,596	221	5,816	5,988
31	1989	5,339	211	5,550	5,641
32	1988	5,051	199	5,251	5,277
33	1987	4,686	185	4,870	4,893
34	1986	4,288	169	4,457	4,488
35	1985	3,886	153	4,039	4,061
36	1984	3,490	138	3,628	3,610

37	1983	3,119	123	3,242	3,133
38	1982	2,629	104	2,733	2,629
39	1981	2,116	83	2,199	2,096

The number of miles added to each age vehicle is generally less than the difference between the unadjusted non-rebound VMT (for a given age) and the mileage schedule. Thus, adding the requisite miles to each age does not distort either the shape of the schedule with age, nor does it create annual usage estimates that are out of line with observed usage. The example shown here uses the baseline alternative to illustrate the reallocation of VMT in 2020, but this reallocation differs by alternative. In less stringent regulatory alternatives, new vehicles are less expensive; this increases new vehicle sales and accelerates the retirement of older vehicles (relative to the baseline). In those cases, the unadjusted non-rebound VMT is higher, Δmiles smaller, and corresponding allocatiou of Δmiles smaller – though still consistently positive.

Commenters encouraged us to use a demand model to avoid creating unrealistic VMT projections that failed to account for factors that exogenously influence total demand for VMT, which we have done here.[1336] Had we instead used the baseline case, regardless of whether it happens to be the most or least stringent alternative, as the non-rebound VMT constraint, both the non-rebound VMT and VMT with rebound would have differed meaningfully from both other government forecasts and from the projections produced by the demand models underlying those forecasts. By producing and enforcing a non-rebound constraiut based on results from a travel demand model, we ensure realism in the projections of total VMT under each regulatory alternative and eusure that the costs and beuefits associated with rebound VMT result only from fuel economy improvements in the regulatory alternatives considered.

(e) VMT resulting from simulation

This section has already demonstrated that total VMT projections from the simulation are consistent with FHWA projections of total light duty VMT using the same set of economic assumptions. Lifetiiue mileage accumulation is now a function of the sales model, scrappage model, mileage accumulation schedules (described in Table VI-120), and the redistribution of VMT across the age distribution of registered vehicles in each calendar year to preserve the non-rebound VMT constraint.

The definition of "non-rebound" VMT in this analysis determiues the additional miles associated with secular fleet turnover and fuel price changes. Conversely, rebouud miles measure the VMT difference due to fuel economy improvements relative to MY2016 (independent of changes in fuel price, or secular fleetwide fuel economy improvement resulting from the continued retirement of older vehicles and their replacement with newer ones). In order to calculate total VMT *with* rebound, we apply the rebound elasticity to the full change in CPM and the initial VMT schedule, but apply the rebound elasticity to the incremental percentage change in CPM between the non-rebound and full CPM calculations to the miles applied to each

[1336] *See, e.g.*, NCAT, Comments, NHTSA-2018-0067-11969, at 31-32; Environmental Group Coalition, Appendix A, NHTSA-2018-0067-12000, at 175-76; UCS, Technical Appendix, NHTSA-2018-0067-12039, at [xxx]; Honda, Supplemental Analysis, NHTSA-2018-0067-1211, at 4.

vehicle during the reallocation step that ensured adjusted non-rebound VMT matched the non-rebound VMT constraint.

Equation VI-13 - Total VMT with rebound miles

$$\sum_{A}^{Ages}\sum_{S}^{Styles}(\mathbf{VMT_{A,S}}\cdot(\mathbf{1}+\%\mathbf{\Delta CPM_{MY,CY}}\cdot\boldsymbol{\varepsilon})+\mathbf{\Delta Miles_{A,S,CY}}\cdot(\mathbf{1}+(\%\mathbf{\Delta CPM_{MY,CY}}-\%\mathbf{\Delta NonRbdCPM_{MY,CY}})\cdot\boldsymbol{\varepsilon}))\cdot\mathbf{Population_{CY,A,S}}$$

Where $VMT_{A,S}$ is the initial VMT schedule by age and body-style, %ΔNonReboundCPM and %ΔCPM are defined in Equation VI-7and Equation VI-6, respectively, and $\Delta Miles_{A,S,CY}$ is the per-vehicle miles added by the reallocation described in Equation VI-12. The additional miles that are added to each vehicle in the reallocation step ($\Delta Miles_{A,S,CY}$) are multiplied by the difference between the percentage changes in CPM (full and non-rebound, respectively) because the %ΔNonRbdCPM was used to derive the allocated miles and using the full CPM change to scale the allocated miles would count that change twice. Taking the difference avoids overestimating the total mileage in the presence of the rebound effect. The "rebound miles" will be the difference between Equation VI-13 and Equation VI-9 for each alternative. To the extent that regulatory scenarios produce comparable numbers of rebound miles in early calendar years, the impacts associated with those miles net out across the alternatives in the benefit cost analysis.

Table VI-124 displays the annual survival-weighted VMT at each age of a MY2025 vehicle, by regulatory class including and reallocation needed to preserve the VMT constraint and all rebound miles (using a 20% rebound effect).[1337]

[1337] Annual survival-weighted VMT is calculated by dividing the annual VMT of a MY cohort by the total population of the cohort purchased. As such, Table VI-123Table VI-123 and Table VI-124Table VI-124 report different types of values.

Table VI-124 - MY2025 lifetime VMT comparisons, by regulatory class

Age	Passenger Car, Final Rule	Passenger Car, NPRM	Passenger Car, 2012 Rule	Light Truck, Final Rule	Light Truck, NPRM	Light Truck, 2012 Rule
0	17,060	17,313	16,761	17,717	17,830	17,828
1	16,420	15,021	16,149	17,036	15,656	16,978
2	15,820	14,907	15,757	16,393	15,371	16,246
3	15,155	14,604	15,143	15,733	15,129	15,599
4	14,534	14,318	14,658	15,071	14,695	15,093
5	13,941	13,931	14,220	14,341	13,975	14,538
6	13,193	12,648	13,635	13,635	12,849	13,159
7	12,480	11,248	12,039	12,902	11,582	12,527
8	11,729	9,761	11,480	12,187	10,319	11,812
9	10,851	8,176	10,838	11,384	8,916	10,875
10	9,947	6,728	10,086	10,522	7,492	9,881
11	8,951	5,400	9,306	9,640	6,279	8,960
12	7,946	4,626	8,505	8,737	5,111	8,090
13	6,907	3,916	7,697	7,776	4,030	7,157
14	5,917	3,506	6,877	6,863	3,513	6,398
15	4,986	3,070	6,037	5,965	3,058	5,651
16	4,155	2,660	5,142	5,130	2,603	4,998
17	3,434	2,282	4,258	4,400	2,208	4,376
18	2,823	1,934	3,396	3,733	1,850	3,765
19	2,328	1,643	2,659	3,183	1,550	3,225
20	1,928	1,400	2,021	2,707	1,293	2,706
21	1,608	1,206	1,533	2,322	1,098	2,249
22	1,354	996	1,189	1,991	939	1,940
23	1,148	820	921	1,717	810	1,640
24	987	678	722	1,497	701	1,452
25	854	557	597	1,308	599	1,299
26	748	463	501	1,161	520	1,214
27	658	385	408	1,030	452	1,068
28	583	320	342	918	395	930
29	522	268	291	821	343	847
30	469	224	82	743	299	754
31	372	189	70	612	266	669
32	293	161	59	501	235	573
33	231	138	48	409	208	479
34	181	117	38	336	186	382
35	141	100	28	275	163	287
36	110	85	19	227	143	201

37	87	74	-	190	126	-
38	66	63	-	153	114	-
39	50	54	-	124	99	-
TOTAL	210,966	175,989	213,513	231,387	183,004	225,844

As earlier portions of this section have shown, the second decade of useful life now shows significantly higher utilization than the NPRM analysis for both passenger cars and light trucks. While the current lifetime accumulation is similar to the values produced in the 2012 final rule, those values were simulated to occur under fuel prices that were consistently 40 percent higher than the prices in this analysis (when adjusted for inflation).[1338] Under comparable prices, lifetime mileage accumulation would have been considerably higher.

(f) Sales, Scrappage and VMT Integration

The VMT construct described above, while an improvement over the version presented in the NPRM for the reasons explained, does not represent the fully integrated model of ownership, usage, and retirement decisions that some commenters argued would be preferred or even required to assess properly the impacts of CAFE/CO_2 standards. In particular, Resources for the Future commented that integrating sales, scrappage and VMT would "make the analysis internally consistent and will account for the fact that households do not make scrappage and vehicle use decisions in isolation."[1339] IPI concurred and expanded in their comment, stating "a unified model of vehicle choice and usage' is necessary."[1340]

The implication of such commenters is that the agencies have ignored important benefits of more stringent standards by not explicitly considering household decisions at the level of household vehicle fleet management. However, the opposite may be true. A recent NBER paper[1341] finds that households engage in attribute substitution while managing the set of attributes in their vehicle portfolios.[1342] In particular, the authors argue that attribute substitution within a household's vehicle portfolio may erode up to 60 percent of the intended fuel economy benefits of the footprint-based CAFE/CO_2 standards, as the higher fuel economy of owned vehicles reduces demand for efficiency in the next bought vehicle, all else equal. This suggests that examining effects at the household level may not be as beneficial, or as meaningful, as some commenters might hope.

Commented [A366]: REVISE: This is not what the commenters said. They said the estimates might be wrong.

While commenters have suggested ambitious models of dynamic relationships at the household level, moreover, it is not clear that such a model is currently possible. Capturing the heterogeneous preferences of households across purchase, usage, and retirement decisions at the same level of detail required to produce meaningful estimates of regulatory compliance costs is beyond the current scope of this analysis. While the agencies agree that expected usage

Commented [A367]: REVISE: See previous comment. It's doubtful anyone expects the model to reproduce every individual household's behavior. Instead, it's a request for a model based in household decision-making. Such a model, e.g., could use representative households, which would set aside some of the true heterogeneity, but would be better micro-founded.

[1338] The 2012 final rule also assumed a 10% rebound effect, which would have further affected lifetime mileage accumulation.
[1339] [Text Forthcoming]
[1340] [Text Forthcoming]
[1341] [Text Forthcoming]
[1342] [Text Forthcoming]

influences the household decision of which vehicle to purchase, how long to hold it, and how to manage the usage and retirement of other vehicles within a household fleet, we do not agree that such a detailed model is a necessary prerequisite to assess the impacts of CAFE and tailpipe CO_2 emissions standards, nor that it is necessarily appropriate to do so given that the agencies are examining aggregate national fleetwide effects of such standards. Furthermore, in the most recent peer review of the CAFE Model, one reviewer remarked that while the sales and VMT would benefit from a household choice model, "the decision to scrap a vehicle (remove it from the national in-use fleet) and the decision to purchase a new vehicle often are not made by the same household. No U.S. national-level transportation demand models (that this reviewer is aware of) tackle the issue with this level of complexity."[1343]

Each iteration of these regulatory analyses has endeavored to improve the accuracy and breadth of modeling to capture better the relevant dynamics of the markets affected by these policies. We intend to address current limitations in future rulemakings, and meanwhile believe that the scope of the current analysis is reasonable and appropriate for informing decision-makers as to the effects of different levels of CAFE and tailpipe CO_2 emissions stringency.

(6) What is the mobility benefit that accrues to vehicle owners?

(a) Mobility benefits in the NPRM analysis

As the proposal noted, the increase in travel associated with the rebound effect provides benefits that reflect the value to drivers and other vehicle occupants of the added – or more desirable – social and economic opportunities that become accessible with additional travel. The fact that drivers and their passengers elect to make more frequent or longer trips to gain access to these opportunities when the cost of driving declines demonstrates that the benefits they gain by doing so exceed the costs they incur, including the economic value of their travel time, fuel and other vehicle operating costs, and the economic cost of safety risks drivers assume. The amount by which the benefits of this rebound additional travel exceed its economic costs equals the net benefits drivers and their passengers experience, usually referred to as increased consumer surplus.

Under the proposal, the fuel cost of driving each mile would have increased as a consequence of the lower fuel economy levels permitted, thus reducing the number of miles that buyers of new cars and light trucks would drive, since the well-documented fuel economy rebound effect operates in reverse.[1344] The agencies' analysis of the proposed rule described the resulting loss in consumer surplus, and calculated its annual value using the conventional approximation, which is one half of the product of the increase in vehicle operating costs per vehicle-mile and the resulting decrease in the annual number of miles driven. Because the value of this loss depends on the extent of the change in fuel economy, it varied by model year, and also differed among the alternative standards that the NPRM considered.

[1343] [Cite Birky, CAFE Model Peer Review]

[1344] Normally, the fuel economy rebound effect refers to an *increase* in vehicle use that results when increased fuel economy reduces the fuel cost for driving each mile.

The agencies' analysis specifically recognized that the economic value of any additional travel prompted by the fuel economy rebound effect must exceed the additional fuel costs drivers incur, plus the economic cost of safety risks they and their passengers assume.[1345] Thus, when vehicle use was projected to decline in response to lower fuel economy, the agencies noted that the resulting loss in benefits must have more than offset both the savings in fuel costs and the value of drivers' and passengers' reduced exposure to safety risks. In the accounting of benefits and costs for the preferred alternative, the loss of benefits associated with reduced mobility was recognized by reporting losses in travel benefits that exactly offset the value of reduced risks of being involved in both fatal and non-fatal crashes.

In addition, the accounting reported a loss in mobility benefits from reduced use of new cars and light trucks, which included a component that exactly offset the fuel savings from reduced driving, together with the loss in consumer surplus that foregone travel would otherwise have provided. Including this first component was necessary to offset the fact that the savings in fuel costs had already been recognized elsewhere in the accounting, by deducting those savings from the increase in fuel costs resulting from lower fuel economy to arrive at the reported *net* increase in fuel costs. Thus, the resulting value of the net loss in travel benefits was exactly equal to the loss in consumer surplus that any travel foregone in response to higher fuel costs would otherwise have provided.

(b) Comments on the agencies' treatment of mobility benefits in the NPRM

The agencies received only two comments referring to their treatment of mobility benefits in the analysis supporting the proposed CAFE and CO_2 standards. The California Air Resources Board (CARB) noted that the accounting of benefits and costs resulting from the proposal included losses in mobility benefits that offset the reduction in fatality costs related to the decline in new vehicle use from the fuel economy rebound effect. While CARB did not comment on the agencies' inclusion of losses in mobility benefits in their accounting, it did object to the fact that the agencies *also* reported the numerical change in fatalities that could be ascribed to the rebound effect, and considered the improvement in safety it reflected when selecting their proposed alternative.[1346] Similarly, the Institute for Policy Integrity (IPI) termed the agencies' reliance on the estimated change in the number of fatalities as partial justification for selecting their preferred alternative as arbitrary, while at the same time arguing that the reduction in driving due to the rebound effect had no net welfare impact.[1347]

In response to these comments, the agencies observe that considering changes in the actual number of fatalities as well as the welfare effects of changes in drivers' and passengers'

[1345] Although it did not attempt to estimate operating costs other than those for fuel or the value of drivers' and passengers' travel time, the benefits from any additional travel that occurs voluntarily must also at least compensate for these costs.

[1346] California Air Resources Board (CARB), NHTSA-2018-0067-11873, at pp. 121.

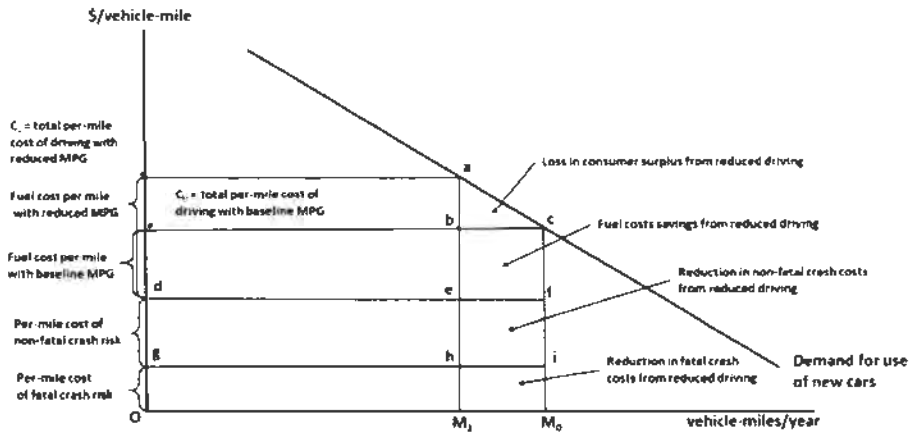
[1347] Institute for Policy Integrity (IPI), NHTSA-2018-0067-12213, at pp. 11. In fact, the agencies did not treat the reduction in driving as having no net impact on welfare, since as explained immediately above, the loss in consumer surplus benefits on the foregone driving was not accompanied by any offsetting cost savings. Therefore, the decline in driving in response to the rebound effect resulted in a net loss in welfare.

exposure and valuation of the risks of being involved in fatal crashes represents a sound approach to assessing the impacts of proposed CAFE and CO_2 standards. The safety implications of alternative future standards are clearly a legitimate and highly visible consequence for the agencies to consider when evaluating their relative merits, as are the implications of changes in the safety risks for the economic welfare of car and light truck users. Thus, the agencies see no inconsistency or duplication in separately considering *both* factors as part of their assessment of alternative future standards.

Commented [A368]: REVISE: The two factors mentioned here (1: number of fatalities and 2: monetized welfare), do not include consideration of the overall risk of fatal and non-fatal injury. The exclusion of overall risk from consideration is a major omission, given the statutory definition and common sense understanding of vehicle safety. (see related comment that follows in 'Simulating safety impacts of regulatory alternatives" section)

(c) Mobility benefits in the final rule

The analysis supporting this final rule continues to treat losses in mobility benefits in the same manner the agencies previously did when analyzing the alternatives considered for the



proposed rule. Because there are several subtleties in this treatment, we have included *Figure VI-49Figure VI-49* below to clarify its details. In the figure, the demand curve shows the relationship of annual use of new cars (and light trucks), which can be thought of as their total or average annual vehicle-miles driven, to the cost per mile of driving.

Figure VI-49 - Treatment of Mobility Benefits from Reduced Driving

Commented [A369]: REVISE: Suggest changing this figure for consistency with the analysis. This figure makes clear that VMT would be expected to change with changes in fatality risk (e.g. through mass reduction, or age/CY effects.) And while this figure is consistent with public comments (Honda), the CAFE analysis implementation constructs VMT independent of the valuation of fatality risk.

The initial cost per mile OC_0 consists of the per mile economic costs of the risks of being involved in fatal and non-fatal crashes, shown by the heights of Og and gd on the vertical axis, together with per-mile fuel costs at the baseline level of fuel economy, the height of segment

dC_0.[1348] Annual miles driven at this initial per-mile cost are shown by the distance OM_0 on the horizontal axis in the figure. When fuel economy declines from its baseline level under one of the regulatory alternatives considered, fuel costs per mile increase from dC_0 to dC_1, but the per-mile economic costs of crash risks (both fatal and non-fatal) are unaffected, so total costs per mile driven rise to OC_1. In response to this increase in the per-mile fuel and total cost of driving, annual use declines to OM_1.

The resulting loss in total benefits when vehicle use declines from OM_0 to OM_1 is the trapezoidal area M_1acM_0, but most of this loss is offset by cost savings from reduced driving, so the net welfare loss is considerably smaller. Specifically, the rectangle M_1hiM_0 represents a reduction in the total economic costs of the risk that drivers and passengers will be involved in fatal crashes when the decline in driving reduces their exposure to that risk. The dollar value of this area thus appears in the agencies' accounting of costs and benefits as *both* a benefit from that reduction in risk and an exactly offsetting loss in benefits from reduced mobility. The same is true of the rectangle hefi, the dollar value of which corresponds to both the reduction in the economic cost of non-fatal crash risks and an identical loss in mobility benefits.

Total fuel costs for driving OM_0 miles are initially the rectangular area dC_0cf, and the decline in driving to OM_1 that results as per-mile fuel and total driving costs rise changes total fuel costs to the rectangle dC_1ae. Because these two areas share rectangle dC_0be, the *net* change in fuel costs reported in the agencies' accounting consists of the dollar value of rectangle C_0C_1ab, minus that of rectangle ebcf. The economic value of the loss in mobility benefits the agencies report in their accounting is the trapezoid eacf, but part of that area consists of rectangle ebcf, and is thus exactly equal to the savings in fuel costs from reduced driving. Since this savings has been already incorporated in the reported change in total fuel costs, and it offsets part of the reported loss in mobility benefits, leaving only the loss in consumer surplus that travelers would otherwise have experienced on foregone reduced driving, the value of triangle bac, as the net loss in mobility benefits.[1349]

This discussion assumes that drivers correctly estimate and consider – or "internalize" – the risks of being involved in both fatal and non-fatal crashes that are associated with their additional driving. However, as is noted in the discussion of the potential effects of the rule on the mass of vehicles and its resulting impact on safety, consumers may value safety risks imperfectly. This possibility is accounted for in the final rule analysis by assuming the portion of the added safety risk that consumers internalize to be 90 percent. In *Figure VI-49Figure VI-49* above, this would be reflected by including a total social cost per mile that is higher than the C_0 and C_1 values for the baseline and reduced MPG cases shown in the graphic by 10 percent of the combined cost of fatal and non-fatal crash risks (the distance Od on the figure's vertical axis), while reducing the costs of safety risks that drivers do consider to 90 percent of the values shown. The higher social costs would offset a portion of the consumer surplus associated with additional mobility (in each case), and result in a small "deadweight loss" over the region where

[1348] Per-mile fuel costs are equal to the dollar price of fuel per gallon, divided by fuel economy in miles per gallon. For simplicity, this figure omits non-fuel operating costs, vehicle maintenance and depreciation, and the value of occupants' travel time. Including them would not change the analysis.

[1349] Thus the change in driving is not welfare-neutral, as JPI asserted in the comment cited previously; instead, it results in a net loss in welfare.

the social cost of driving exceeds the demand curve. These impacts are also fully accounted for in the final rule analysis.

(7) What is the sales surplus that accrues to vehicle owners?

Commented [A370]: REVISE: The primary benefit of increased vehicle ownership is the use of the vehicle. There may be an additional benefit from being in a vehicle with improved quality, but the primary benefit is the mobility benefit measured above. There seems to be double-counting with that mobility benefit.

Buyers who would not have purchased new models with the baseline standards in effect but decide to do so in response to the changes in new vehicles' prices with less demanding standards in place will also experience increased welfare. Collective benefits to these "new" buyers are measured by the consumer surplus they receive from their increased purchases.

At the proposed rule stage, the agencies elected to exclude the consumer surplus associated with new vehicle purchases because "it is not entirely certain that sales of new cars and light trucks [would] increase in response to [the] proposed action."[1350] Consumer surplus is a fundamental economic concept and represents the net value (or net benefit) a good or service provides to consumers. It is measured as the difference between what a consumer is willing to pay for a good or service and the market price. OMB circular A-4 explicitly identifies consumer surplus as a benefit that should be accounted for in cost-benefit analysis. For instance, OMB Circular A-4 states the "net reduction in total surplus (consumer plus producer) is a real cost to society," and elsewhere elaborates that consumer surplus values be monetized "when they are significant."[1351]

The decision to exclude consumer surplus for new vehicles at the proposed rule stage was an error and inconsistent with OMB's guidance on regulatory analysis. The agencies are confident that lower vehicle prices, holding all else equal, should stimulate new vehicle sales and by extension produce additional consumer surplus. That preliminary decision was also inconsistent with other parts of the agencies' analysis. For instance, the agencies calculate the lost consumer surplus associated with reductions in driving owing to the increase in the cost per mile in less stringent regulatory cases, as discussed in [Mobility Benefits Section]. The surpluses associated with sales and additional mobility are inextricably linked as they capture the direct costs and benefits accrued by purchasers of new vehicles. The sales surplus captures the savings to consumers when they purchase cheaper vehicles and the additional mobility measures the cost of higher operating expenses. It would be inappropriate to include one without the other.

Commented [A371]: REVISE: That's in the cost calculation and shouldn't be duplicated.

The shaded area in Figure VI-50Figure VI-50 reflects the consumer surplus calculated for new vehicle sales. Line C_0 reflects the baseline vehicle cost. The final rule is expected to reduce the cost of light duty vehicles, as represented by dotted line C'. Consistent with other sections of the analysis, the agencies assume that consumers value 30 months of fuel savings. Under the final rule, consumers are expected to experience higher fuel costs than they would under the baseline scenario, shifting costs from line C' to line C_1. The consumer surplus is equal to the area under the curve between Q_0 and Q_1.[1352]

[1350] *See* PRIA at 954.
[1351] OMB Circular A-4, at 37-38.
[1352] The exact calculation is 0.5 * the increase in sales * the reduction in the cost of light duty vehicles net of the increased fuel cost.

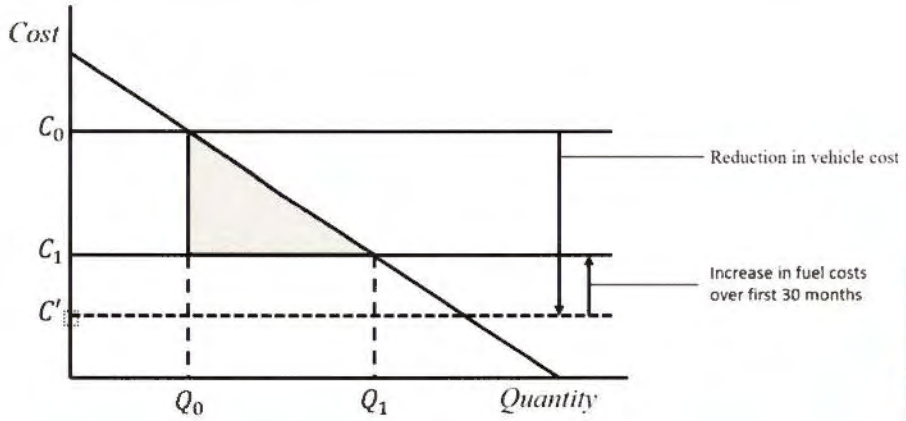


Figure VI-50 – [Text Forthcoming]

(8) Forgone improvements to other vehicle attributes

~~The agencies recognize the likely possibility that stricter standards may require manufacturers to make tradeoffs in other vehicle features that compete with fuel economy that at least some buyers may value more highly. We also recognize that buyers may have time preferences that cause them to discount the future at higher rates than the agencies are directed to consider in their regulatory evaluations. In either case, the agencies' central analysis may overstate both the net private and social benefits from adopting more stringent fuel economy and CO_2 emissions standards. For instance, Table [xx] shows that the CAFE final rule would generate [$x] billion in total social net benefits using a 7% discount rate, but without the large net private loss of [$26] billion, the net social benefits would equal the external net benefits, or [$34] billion. Therefore, given that government action cannot improve net social benefits absent a market failure, if no market failure exists to motivate the [$xx] billion in private losses to consumers, the net benefits of these final standards are [$xx] billion.~~

~~To explore further the possibility that the primary analysis is incomplete regarding the consumer benefits of other vehicle attributes, the agencies conducted a sensitivity analysis using a conservative estimate of this value. In the NPRM analysis, the agencies considered the lost value of other vehicle attributes in two sensitivity cases that reduced the total consumer benefit.[1555] The agencies received several comments suggesting that the analysis of other vehicle attributes lost could be improved. For example, CARB commented that the "analyses do not adequately model how vehicle values will change in response to improving fuel economy, or the~~

[1555] See PRIA at 954. See also PRIA at 1539.

Commented [A372]: REVISE: This section requires signicant revisions, or complete removal, since the conclusions are based on a technical analysis which assumes that vehicle utility is maintained across the regulatory alternatives.

Commented [A373]: DELETE: It is incorrect to conclude that the analysis may "overstate" benefits (an if "may" is speculative, what is the purpose of claiming "overstating" vs. "understading").

This analysis applies technologies absent regulation based on the 2.5year payback assumption. So the technology costs (and associated increase in purchase price) create a lower bound of net private and social benefits for more stringent standards, as long as the analysis does indeed maintain vehicle utility, as argued.

Commented [A374]: DELETE: A straw-man argument. One could just as easily say "if consumers don't value mobility" and it would be just as unjustified as saying "if no market failure exists".

It's hard to comment without the numbers, but presumably the intent is to present private loss value here of the final standards without accounting for a forgone improvement value, and then include the forgone improvement in the net benefits number. But then the statement won't make sense, because the forgone improvement value is being considered a private loss…

Commented [A375]: DELETE: This discussion/sensitivity is one-sided and abstract, with no real-life exammples given. Vehicle attributes/utility are sometimes improved, inevitably, by efficiency technologies. For example, mass reduction in pickup-trucks results in significant acceleration improvement when towing capacity is maintained (as it is in this analysis)

Furthermore, NHTSA has informed us that the updated analysis, while improved from the NPRM, still maintains a small performance increase (1%) for the more stringent standads, which is counter to argument that consumers will experience some abstract 'forgone improvement'

In other words, this sensitivity is both "incomplete" and not "conservative" regarding the consumer benefits of other vehicle attributes.

~~competing effects of other attributes.[1,2,3] In response to commenters, the agencies have revised their sensitivity analyses to model better the impact of the standards on other vehicle attributes.~~

~~The agencies considered, such as they did in the NPRM, offsetting the net private costs associated with enabling more choices in fuel-saving technologies in a manner similar to rebound driving. However, the agencies believe that this approach is unnecessary, as such an analysis would produce nearly identical net benefits to the external net benefits—which the primary analysis already generates. Furthermore, given that consumers are free to choose more fuel efficient vehicles absent more stringent regulations, applying the rational consumer logic from above suggests that consumers who prefer certain vehicle attributes instead of fuel economy necessarily value those attributes more than the fuel efficiency technologies they voluntarily forgo. As such, a sensitivity analysis including a value for other vehicle attributes should more than offset the net private costs to consumers from the primary analysis.~~

Commented [A376]: DELETE: Consumers are not free to choose vehicles if they don't exist. For example, in MY2010 prior to the 2012 FRM there were no 200 mile range EVs, 30mpg SUVs, or minivans that got better than 20 mpg.

Commented [A377]: DELETE: It is not correct that sensitivity where consumers can weigh choices with varying degrees of utility would "more than offset net private costs" of the central analysis. In the case of a perfectly informed and rational consumer (a strong assumption), vehicle utility is known at the time of vehicle purchase, and consumers and producers make the rational decision to either choose vehicles with utility maintained and pay costs as represented in this analysis by the technology costs, or forego some of that utility, which for rational consumers would only occur if it lowered private net costs.

In other words, any sensitivity analysis assuming a rational consumer could not possibly increase the net private costs of greater stringency, unless the CAFE model's technical analysis does not actually maintain vehicle performance and utility, despite the strenuous arguments elsewhere in this document that it does.

~~In the final rule, instead of keeping the same approach as the preliminary analysis, for today's analysis the agencies have elected to estimate consumer benefits of other vehicle attributes in a sensitivity case using similar logic to that used for the sales and scrappage models. In those models, the agencies assume that consumers value thirty months of undiscounted fuel savings. Given this assumption, it would be reasonable for the agencies then to assume that the value of other vehicle attributes must be greater than the fuel savings for the remaining term of the useful life of the vehicle—as these are fuel economy savings that consumers are clearly willing to forgo. The agencies acknowledge that vehicles are typically sold more than once, but evidence suggests that fuel savings are capitalized into sales prices in the used car market.[4,5,6] If this is the case, new car purchasers would internalize the additional value on resale owing to fuel efficiency technologies, and the fuel savings over the remaining useful life less thirty months would be an appropriate value to use for the value of other vehicle attributes. Nevertheless, the agencies have elected to be conservative and, instead, opted to use the fuel savings over the first seventy-two months (less the first thirty months), which approximates the amount of time the first owner typically holds a new vehicle.[7,8,9] This value is referred to as the "implicit opportunity cost" of forgoing other vehicle attributes in favor of increased fuel economy for using their scarce financial resources to invest in savings or the purchase of other goods that they~~

Commented [A378]: DELETE: Repeating above comment, it's NOT a reasonable approach given the assumed rational and informed new-vehcicle buyers who, in a perfect market have the choice of a range of vehicle options spanning both reduced-utility and maintained-utility vehicles. While the primary analysis considers only maintained-utility vehicles, consumers could only be better off (or at worst, the same) with the option of reduced-utility vehicles to choose from.

Alternatively, this discussion would be supportable if it were based on actual evidence of an inability to maintain vehicle quality, and estimate the value of that loss. The current exercise is based on an unsupported assumption that it's necessary to give up fuel savings to get other attributes. The analysis elsewhere shows that it is possible to maintain other vehicle qualities while providing fuel savings. So the underlying assumption of this analysis is unfounded.

Commented [A379]: DELETE: The approach is not necessarily conservative, as explained in above comments, since technology costs are an upper bound to private and societal costs given the utility-neutral technology assessment of this rule.

~~[1] CARB, Detailed Comments, NHTSA-2018-0067-11877 at 180.~~
~~[2] For further discussion of the evidence, see [Sales section].~~
~~[3] There are several reasons why 72 months is an appropriate approximation. According to a report from the Federal Reserve bank of Chicago the average new vehicle is owned for over 77 months in 2015. From the same report, the average new car loan term was over 67 months in 2016. (https://www.chicagofed.org/publications/working-papers/2018/2018-04, accessed December 23, 2019) Data from R.L. Polk suggest that the average new car is held for 71.4 months (as cited in https://www.autotrader.com/car-shopping/buying-car-how-long-car-you-expect-car-last-240725).~~

~~prefer more than fuel economy).[xxx] showing a cost savings for less-stringent alternatives.[xxx] Unlike the sales surplus, which measures the consumer surplus of new vehicle buyers entering the market, the implicit opportunity cost contained in this sensitivity case represents the forgone benefits to consumers the model assumes would have purchased a vehicle regardless of the standards (but would prefer to take the upfront cost of fuel economy technologies and invest that money elsewhere, whether it be on different vehicle attributes or different goods altogether). These results are shown in Section [xxx].~~

~~The agencies note that the primary analysis of the final rule features a conservative treatment of private benefits and costs that may bias the results in the favor of more stringent regulatory alternatives. This bias arises from the agencies' treatment of rebound driving. The agencies assume that drivers make a rational decision when electing to drive additional miles, which considers not only the risks the additional driving poses to their own lives and property, but also most of the risks their behavior poses to their passengers as well as the person and property of other road users. In such a case, drivers "internalize" most of these risks, and it can be assumed that benefits to drivers must be more valuable to them than the risks they considered when deciding whether to undertake the additional driving. Therefore, the agencies have appropriately offset the loss in safety benefits, which are associated with the increased cost of driving in the final rule, with commensurate lost benefits of additional driving.~~

~~In contrast, the agencies can be *assured* the private benefits and costs of fuel saving technologies (aside from the external environmental damages) are internalized – as there is no doubt that the owners of the vehicles will accrue the fuel costs savings. The agencies believe it would be entirely contradictory to assert that consumers are rational, informed, and considerate enough to internalize the risks of additional driving to themselves, their passengers, as well as other drivers and passengers; but are not similarly rational and informed enough to consider the additional fuel costs of purchasing a vehicle without a particular fuel saving technology. After all, existing regulations require that the estimated annual fuel costs of a vehicle are disclosed *on the new vehicle a consumer intends to purchase* – and no such disclosure exists for the risks associated with driving a rebound mile. The agencies' decision to offset rebound miles, but not net private costs stemming from enabling more choices in fuel-saving technologies, *significantly* favors more stringent alternatives.~~

Commented [A380]: DELETE: Again, just the opposite. The approach used in the primary analysis assumes tech costs as an upper bound to private costs.

Commented [A381]: DELETE: Not correct. This description was applicable for the NPRM where drivers were assumed to fully value risk of accidents, but is no longer true for the FRM analysis, which assumes that drivers only partially value accident risk (and, by extension, not value the risk of accidents to others).

Note that EPA had previously recommendend that NHTSA continue to use the "Accident" cost per mile to capture the costs of property damage externalities, but NHTSA pointed out that the non-fatal costs include property-damage only accidents.

Commented [A382]: DELETE: Not correct. Again, this would only be a potential bias if the analysis assumed that drivers fully internalize accident risk. For the FRM analysis, that it not the assumption.

In any case, a potential bias of assuming full-valuation would likely not be significant, since it would be offset to some extent by another assumption made in this analysis that travel demand and VMT is totally unresponsive to accident risk.

(9) Refueling benefit

Increasing CAFE/CO_2 standards, all else being equal, affect the amount of time drivers spend refueling their vehicles in several ways. First, they increase the fuel economy of ICE vehicles produced in the future and, consequentially, decrease the number of refueling events for

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~~[xxx] These vehicle attributes may include any that consumers may value and are not explicitly modeled to be neutral across regulatory alternatives. For instance, trim levels, entertainment systems, crash avoidance technologies, etc may be sacrificed to pay for higher fuel economy technology levels.~~

~~[xxx] The implicit opportunity cost must be considered a value that consumers place on other vehicle attributes that is net of the cost of those attributes. This is the forgone consumer surplus of other vehicle attributes. As such it is appropriately additive to the technology cost-savings estimated in the primary analysis.~~

those vehicles. Second, given increased production costs, they reduce sales of new vehicles and scrappage of existing ones, causing more VMT to be driven by older and less efficient vehicles which require more refueling events for the same amount of VMT driven. Finally, they may change the number of electric vehicles that are produced, and shift refueling to occur at a charging station, rather than at the pump—changing per-vehicle lifetime expected refueling costs. While there are multiple ways that fuel economy standards alter refueling costs, the proposal accounted for only the first. Before the inclusion of the sales and scrappage models, which first appeared in the NPRM analysis for the first time a CAFE/ CO_2 rulemaking, the agencies did not have the means to capture the other two effects. While the agencies modeled the sales and scrappage effects, they did not extend the results to refueling time. This oversight was noted by commenters, and the final rule model now includes these additional factors. The basic calculation for all three effects is the same: the agencies multiply the additional amount of time spent refueling by the value of time of passengers, which is assumed to be the same for all three effects.

(a) Value of Time

The calculation of the value of time remains relatively unchanged from the proposal and follows the guidance from DOT's 2016 *Value of Travel Time Savings* memorandum ("VTTS Memo").[1359] The economic value of refueling time savings is calculated by applying valuations for travel time savings from the VTTS Memo to estimates of how much time is saved across alternatives.[1360]

IPI commented that the agencies used old data to calculate the refueling benefit in the proposal. Specifically, IPI pointed out that the data used in the proposal seemed "to come from the 2003 version of [the VTTS Memo]."[1361] For the final rule, the analysis uses the most recent VTTS memo along with updated wages. The value of travel time depends on average hourly valuations of personal and business time, which are functions of annual household income and total hourly compensation costs to employers. The nationwide median annual household income, $56,516 in 2015, is divided by 2,080 hours to yield an income of $27.20 per hour. Total hourly compensation cost to employers, inclusive of benefits, in 2015$ is $25.40.[1362] Table VI-125Table VI-125 demonstrates the agency's approach to estimating the value of travel time ($/hour) both urban and rural (intercity) driving. This approach relies on the use of DOT-recommended weights that assign a lesser valuation to personal travel time than to business travel time, as well as weights that adjust for the distribution between personal and business

[1359] United States Department of Transportation , The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations, (2016), available at https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20V.
[1360] VTTS Memo Tables 1, 3, and 4.
[1361] IPI, Appendix, NHTSA-2018-0067-12213, at 51.
[1362] *Ibid* at 11.

travel.[1363] In accordance with DOT guidance, wage valuations are estimated with base year 2015 dollars and end results are adjusted to 2018 dollars.

Table VI-125 - Estimating the Value of Travel Time for Urban and Rural (Intercity) Travel ($/hour, 2015 Dollars)

Urban Travel			
	Personal Travel	**Business Travel**	**Total**
Wage Rate ($/hour)	$27.20	$25.40	-
DOT - Recommended Value of Travel Time Savings, as % of Wage Rate	50%	100%	-
Hourly Valuation (=Wage Rate * DOT-Recommended Value)	$13.60	$25.40	-
% of Total Urban Travel	95.4%	4.6%	100%
Hourly Valuation (Adjusted for % of Total Urban Travel)	$12.97	$1.17	**$14.14**
Rural (Intercity) Travel			
	Personal Travel	**Business Travel**	**Total**
Wage Rate ($/hour)	$27.20	$25.40	
DOT - Recommended Value of Travel Time Savings, as % of Wage Rate	70%	100%	
Hourly Valuation (=Wage Rate * DOT-Recommended Value)	$19.04	$25.40	
% of Total Rural Travel	78.6%	21.4%	100%
Hourly Valuation (Adjusted for % of Total Rural Travel)	$14.97	$5.44	**$20.40**

Estimates of the hourly value of urban and rural travel time ($14.14 and $20.40, respectively) shown in the above table, must be adjusted to account for the nationwide ratio of urban to rural driving.[1364] This adjustment, which gives an overall estimate of the hourly value of travel time—independent of urban or rural status—is shown in Table VI-126Table VI-126.

[1363] Business travel is higher than personal travel because an employer has additional expenses, *e.g.* taxes and benefits costs, above and beyond an employee's hourly wage. In the proposal, the agencies erroneously used the same value for personal and business travel, which was inconsistent with the VTTS Memo.

[1364] Estimate of Urban vs. Rural travel weights from FHWA December 2018 Traffic Volume Trends, Monthly Report, Table 2 - Cumulative Monthly Vehicle-Miles of Travel in Billions. Available at https://www.fhwa.dot.gov/policyinformation/travel_monitoring/18dectvt/page3.cfm.

Table VI-126 - Estimating Weighted Urban/Rural Value of Travel Time ($/hour, 2015 Dollars)

	Unweighted Value of Travel Time ($/hour)	Weight (% of Total Miles Driven)	Weighted Value of Travel Time ($/hour)
Urban Travel	$14.14	69.9%	$9.89
Rural Travel	$20.40	30.1%	$6.14
Total	-	100.0%	$16.03

Note that the calculations above consider the value of travel time for only one occupant. To estimate fully the average value of vehicle travel time per vehicle, the agencies must account for the presence of all additional passengers during refueling trips. The agencies estimated average vehicle occupancy using survey data gathered as part of our 2010-2011 National Automotive Sampling System's Tire Pressure Monitoring System (TPMS) study.[1365] The study was conducted at fueling stations nationwide and researchers made observations regarding a variety of characteristics of thousands of individual fueling station visits from August, 2010 through April, 2011. Among these characteristics of fueling station visits, the total number of occupants per vehicle were observed. Average vehicle occupancy was calculated and multiplied by the value of travel time per occupant. As shown below in Table VI-127Table VI-127 this adjustment is performed separately for passenger cars and for light trucks, yielding occupancy-adjusted valuations of vehicle travel time during refueling trips for each fleet.

Table VI-127 - Estimating the Value of Travel Time for Light-Duty Vehicles ($/hour, 2015 Dollars)

	Passenger Cars	Light Trucks
Average Vehicle Occupancy During Refueling Trips (persons)	1.21	1.23
Weighted Value of Travel Time ($/hour)	$16.03	$16.03
Occupancy-Adjusted Value of Vehicle Travel Time During Refueling Trips ($/hour)	$19.39	$19.71

[1365] 2011 Tire Pressure Monitoring Systems Special Study, available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812410 (updated 2017).

Lastly, the occupancy-adjusted value of vehicle travel time is converted to 2018 dollars using the GDP deflator as shown below.[1366]

Table VI-128 - Value of Vehicle Travel Time in 2018 Dollars ($/hour, 2018 Dollars)

	Passenger Cars	Light Trucks
Occupancy-Adjusted Value of Vehicle Travel Time During Refueling Trips ($/hour)	$20.45	$20.79

IPI commented that the exclusion of children from the NPRM's refueling time analysis was inconsistent with DOT's 2016 *Value of Travel Time Savings* memorandum ("VTTS Memo"). IPI claimed that the VTTS Memo "consider[ed] whether the value of travel time is different for parents versus children, but ultimately conclude[d] that 'it must be assumed that all travelers' VTTS are independent and additive.'" IPI also quoted language from page 13 of the VTTS Memo that "[a]lthough riders may be a family with a joint VTTS or passengers in a car pool or transit vehicle with independent values, these circumstances can seldom be distinguished [...] therefore, all individuals are assumed to have independent values." and that it is "inappropriate to use different income levels or sources for different categories of traveler."[1367]

IPI further asserted that excluding passengers under age 16 from the calculation of travel time savings was inconsistent with the best practices of benefit-cost analysis. IPI noted that Circular A-4 does not distinguish between children and adults except when monetizing health effects. IPI then cited Dale Whittington and Duncan MacRae as stating "there is a clear consensus that children should be counted in cost-benefit analysis." Finally, IPI commented that Congress intended that the agencies consider the economic impact to children when setting standards.[1368]

The agencies point out that the first passage from the VTTS Memo cited by IPI does not conclude, or even deliberate, that the VTTS of children is the same as adults, but instead states that the VTTS of children, parents and other passengers should be independent and additive.[1369] Assuming that the opportunity cost of children's time is zero is compatible with this practice. Likewise, IPI concluded from the text on page 12 that it was inappropriate to use different incomes for children. However, IPI's analysis suffers from two errors. The two quotes from page 12 reside in a section of the VTTS Memo entitled *Special Issues*, which provides guidance on three distinct topics. The first quoted text comes from a paragraph advising how to treat

[1366] Bureau of Economic Analysis, NIPA Table 1.1.9 Implicit Price Deflators for Gross Domestic Product, available at https://apps.bea.gov/iTable/index_nipa.cfm.
[1367] *See* IPI, Appendix, NHTSA-2018-0067-12213, at 52-53 (citing United States Department of Transportation ("DOT"), The Value of Travel Time Savings: Departmental Guidance for Conducting Economic Evaluations, (2016), available at https://www.transportation.gov/sites/dot.gov/files/docs/2016%20Revised%20V).
[1368] *See* IPI, Appendix, NHTSA-2018-0067-12213, at 53-54 (internal citations omitted).
[1369] *See* VTTS Memo at 5.

vehicles with multiple passengers, while the second is from an ensuing topic about passenger incomes. It is baseless to assume that the conclusion of the second topic holds true for the first.

Second, assuming IPI intended to comment that age is a "category of traveler" for which "it is inappropriate to use different income levels," the agencies note that such an interpretation is tenuous. The VTTS Memo clearly recognizes that some categories of travelers should have different levels of income,[1370] and provides two examples.[1371] As children are not part of the workforce, they do not have wage incomes. Therefore, it is not wild speculation that they do not bear a financial opportunity cost associated with their time spent in vehicles during refueling.[1372] As such, excluding children from the calculation of the refueling benefit is consistent with DOT's guidance.

Turning to IPI's comments on best practices and Congress' intent, the agencies agree that the benefit-cost analysis should include children when appropriate. The majority of the components of the CAFE model (e.g., safety analyses) include children. However, children are excluded from the analysis when it is appropriate (e.g. employment). For this specific valuation, it is reasonable to assume the value of a child's time is not equivalent to an adult's. However, in acknowledgement of any uncertainty, a sensitivity analysis has been included in [Section xxx] demonstrating the impact of valuing children's time as equal to adults' by including them in the average vehicle occupancy rates applied in the refueling analysis and using the full VTTS for personal travel. As this would be the maximal value for children, the combination of this sensitivity analysis and the main analysis show the full range of possible valnes. As is clearly demonstrated by the sensitivity analysis, the effect of this issue is so minor that it is, at most, a very small factor in the decision-making. The agencies will continue to consider this issue in future CAFE and CO_2 rulemakings.

IPI also noted that the only portion of the TPMS pnblicly available was the "User's Coding Manual." Specifically, IPI argued that "the agencies' failure to make available the full data and methodology used to calculate these average occupancy figures frustrates any meaningful public review." The agencies disagree. IPI was able to submit a meaningful comment about the agencies' decision to exclude children from the occupancy-adjusted value of vehicle travel time. Furthermore, commenters knew that the agencies intended to use occupancy estimates to calculate the refueling benefit; however, the agencies did not receive any alternative estimates or methodologies from commenters.

[1370] The full text quoted by IPI reads, "[*e*]*xcept for specific distinctions*, we consider it inappropriate to use different income levels or sources for different categories of traveler." VTTS Memo at 12 (emphasis added). The VTTS Memo further contemplates that it is appropriate to assign different incomes if "estimates [of income are] derived by reliable and focused research [...] in specific cases." *Id.*

[1371] The VTTS Memo provides specific guidance on how to differentiate between personal and business travel, and air or high speed rail from other modes of transportation. *See* VTTS Memo at 12.

[1372] The TMPS study affords the agencies the opportunity to distinguish between adults and passengers, a luxury not avaliable in every instance. Furthermore, there may be certain instances where it is appropriate to value the VTTS of children the same as adults, *e.g.* rules focusing primarily on the VTTS of children.

(b) Accounting for Improved Fuel Economy of ICE Vehicles

The methodology for calculating the refueling benefits associated with improved fuel economy in new vehicles remains unchanged from the proposal. The CAFE model calculates the number of refueling events for each ICE vehicle in a calendar year. This is calculated as the number of miles driven by each vehicle in that calendar year divided by the product of that vehicle's on-road fuel economy, tank size, and an assumption about the average share of the tank refueled at each event, as follows:

$$Refuel\ Events_{CY,Veh} = \frac{Miles_{CY,Veh}}{FE_{Veh} * Tank_{Veh} * Share_{Veh}}$$

The model then computes the cost of refueling as the product of the number of refueling events, total time of each event and value of the time spent on each event (computed as average salary), as below:

$$Cost_{CY,Veh} = Refuel\ Events_{CY,Veh} * (Event\ Time_{Veh}) * Time\ Value$$

The event time of a vehicle is calculated by summing a fixed and variable component. The fixed component is the number of minutes it is assumed each event takes, independent of any assumptions about tank size or share refueled at each event (the time it takes to get to and from the pump). The variable component is the ratio of the average number of gallons refueled for each event (the product of the tank size and share refueled) and the rate at which gallons flow from the pump. This is shown below:

$$Event\ Time_{Veh} = Fixed_{Veh} + \frac{Tank_{Veh} * Share_{Veh}}{Rate}$$

In order to calculate the refueling time cost, as described above, the CAFE model takes the following inputs: the value of time, the fixed time component of each refueling event, share of the tank refueled at each event, rate of flow of fuel from the pump, and vehicle tank size. The first of these is taken from DOT guidance on travel time savings. The fixed time component, share refueled, and rate of flow are calculated from survey data gathered as part of our 2010-2011 National Automotive Sampling System's Tire Pressure Monitoring System (TPMS) study.[1373] Finally, the vehicle fuel tank sizes are taken from manufacturer specs for the reference fleet and historical averages are calculated from popular models for the existing vehicle fleet, as described, below, in the section on including the legacy fleet.

The agencies estimated the amount of saved refueling time using survey data gathered as part of the aforementioned TPMS study. In this nationwide study, researchers gathered information on the total amount of time spent pumping and paying for fuel. From a separate sample (also part of the TPMS study), researchers conducted interviews at the pump to gauge the

[1373] 2011 Tire Pressure Monitoring Systems Special Study, available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812410 (updated 2017).

distances that drivers travel in transit to and from fueling stations, how long that transit takes, and how many gallons of fuel are purchased.

The agencies focused on the interview-based responses in which respondents indicated the primary reason for the refueling trip was due to a low reading on the gas gauge. Such drivers experience a cost due to added mileage driven to detour to a filling station, as well as added time to refuel and complete the transaction at the filling station. The agencies believe that drivers who refuel on a regular schedule or incidental to stops they make primarily for other reasons (e.g., using restrooms or buying snacks) do not experience the cost associated with detouring in order to locate a station or paying for the transaction, because the frequency of refueling for these reasons is unlikely to be affected by fuel economy improvements. This restriction was imposed to exclude distortionary effects of those who refuel on a fixed (*e.g.*, weekly) schedule and may be unlikely to alter refueling patterns as a result of increased driving range. The relevant TPMS survey data on average refueling trip characteristics are presented below in Table VI-129Table VI-129.

Table VI-129 - Average Refueling Trip Characteristics for Passenger Cars and Light Trucks

	Gallons of Fuel Purchased	Round-Trip Distance to/from Fueling Station (miles)	Round-Trip Time to/from Fueling Station (minutes)	Time to Fill and Pay (minutes)	Total Time (minutes)
Passenger Cars	10	0.97	2.28	4.1	6.38
Light Trucks	13	1.08	2.53	4.3	6.83

IPI commented that it was inappropriate for the agencies to exclude benefits from reducing the frequency of refueling events where the primary reason for stopping at a fuel station was not to refuel a vehicle. IPI agrued that fuel efficiency impacts from relaxed standards would affect all drivers regardless of their rationale for refueling, by requiring either more frequent or marginally longer refueling events.[1374] We note that the language in the NPRM suggested that the agencies eliminated 40% of the potential benefit from fewer refueling stops—where 40% represents the fraction of refueling stops that were routinely scheduled or otherwise not made in response to a low fuel reading[1375]—and this appears to have been the origin of IPI's concern. In fact,the agencies did *not* apply a 40% discount factor to the refueling benefits; instead, we calculated the total number of additional refueling events that would result from alternative CAFE levels, and valued them based on an assumption that their characteristics (e.g. vehicle occupancy) would match those of drivers who refueled due to a low fuel reading.

To the extent that lower fuel economy affects those who refuel on a routine schedule or incidental to stops made primarily for other reasons, the per-event cost would actually be limited

[1374] IPI, Appendix, NHTSA-2018-0067-12213, at 54-55.
[1375] *See* 83 FR 43088 (Aug. 24, 2018).

to the extra time spent pumping a slightly larger volume of fuel. However, we note that by assuming that all extra fuel consumed under lower CAFE standards results in added refueling trips, we are adopting a conservative assumption, in the sense that it maximizes the disbenefits of alternatives to the current standards.

IPI also expressed concern that the agencies may have excluded the fuel costs and added emissions from additional miles driven in the course of the more frequent refueling events that would be required with more lenient CAFE standards, and correspondingly lower on-road fuel economy.[1376] In the NPRM, the agencies asserted that these added costs are reflected in their overall estimates of fuel cost savings, while any increase in emissions is also reflected in the reported changes in total emissions. However, IPI noted that the agencies did not clearly explain how these cost savings and emissions reductions are actually accounted for in their methodology.

The agencies' methodology fully accounts for both of these impacts through its calculation of changes in the use of new cars and light trucks due to the fuel economy rebound effect, which captures the impact on their aggregate use (VMT) that results from changes in the fuel cost of driving each mile. Studies that estimate the rebound effect analyze the relationship between VMT per time period and fuel economy or per-mile fuel costs, using data for individual vehicles, fleet-wide average values, or aggregate estimates for an entire fleet. Regardless of the level of aggregation they employ, their measures of vehicle use invariably include travel for all purposes, including any extra miles driven in the course of refueling.

Thus, the estimates of the rebound effect—the response of vehicle use to changes in fuel economy or per-mile fuel costs—inevitably capture any change in the number of miles driven for the purpose of refueling that occurs in response to higher or lower fuel economy. This change reflects the net effect of more or less frequent refueling trips required by their baseline or "pre-rebound" level of use, and any change in the number of refueling trips associated with increased or reduced driving in response to the rebound effect.

As a consequence, the agencies' estimates of changes in aggregate fuel consumption and fuel costs incorporate—that is, are net of—the volume and cost of fuel consumed by changes in vehicle use that result from the rebound effect, *including* any change in driving associated with more or less frequent refueling. Similarly, the agencies' estimates of changes in emissions resulting from vehicle storage and use (referred to as "tailpipe" or "downstream" emissions) are derived by applying per-mile emission factors to changes in aggregate vehicle travel, so they necessarily incorporate changes in vehicle use for all purposes, including more or less frequent refueling.

Furthermore, as the agencies demonstrated in the proposal with a practical example, the benefit associated with fewer miles spent refueling is *less than* 23¢ per year for new vehicles.

[1376] IPI, Appendix, NHTSA-2018-0067-12213, at 55.

The cumulative impact of this benefit amounts to less than one tenth of percent of the costs of the rule.[1377]

Because all of the alternative standards evaluated in this rulemaking would permit lower fuel economy levels than under the baseline standard, per-mile driving costs would be higher and total vehicle use would decline in response. Although some (perhaps most) new vehicles would require more frequent refueling, the agencies' estimates of the change in aggregate use of new vehicles reflects (i.e., is net of) any increase in driving associated with more frequent refueling stops. As a result, the agencies' estimates of changes in total fuel consumption, aggregate fuel costs, and emissions resulting from the lower fuel economy levels that relaxing CAFE standards would permit reflect the *net* reduction in use of new cars and light trucks due to the fuel economy rebound effect, after considering any additional miles that would be driven in the course of more frequent refueling stops.

We assume that all of the round-trip time necessary to travel to and from the fueling station is a part of the fixed time component of each refueling event. However, some portion of the time to fill and pay is also a part of the fixed time component. For this reason, we use an assumption that each refueling event has a fixed time component of 3.5 minutes.

Cars have average tank sizes of about 15 gallons, SUVs/vans of about 18 gallons, and pickups of about 27 gallons (*see* Table VI-132Table VI-132 through Table VI-134Table VI-134 in the section on including the legacy fleet). It is a reasonable assumption that the average passenger car has a tank of 15 gallons and the average light truck has a tank of 20 gallons (there are more SUVs/vans than pickups in the light truck fleet). From these assumptions, we can calculate that the average refueling event fills approximately 65% of the fuel tank for both passenger cars and light trucks. This value is used as an input in the CAFE model for all three body styles (cars, SUVs/vans, and pickups).

Finally, the rate of the pump flow can be calculated either as the total gallons pumped over the assumed variable time component (approximately 3 minutes) or as the difference in the average number of gallons filled between light trucks and passenger cars over the difference in the time to fill and pay between the two classes. The first methodology implies a rate between 3 and 4 gallons per minute. Although the second methodology implies a rate of 15 gallons per minute, there is a legal restriction on the flow of gasoline from pumps of 10 gallons per minute.[1378] Thus, we assume the rate of gasoline pumps ranges between 4 and 10 gallons per minute, and we use 7.5 gallons per minute—a value slightly above the midpoint of that range—as the average flow rate in the CAFE model.

The calculations described above are repeated for each future calendar year that light-duty vehicles of each model year affected by the CAFE standards considered in this rule would remain in service for each regulatory alternative. The resulting cumulative lifetime valuations of

[1377] *See* 83 FR at 43088. Also, note that the 23 cents estimate was derived for a less stringent alternative than today's standards and included taxes which would have been removed had the agencies calculated this number separately.

[1378] 40 CFR 80.22 (j), Regulation of Fuels and Fuel Additives - subpart B. Controls and Prohibitions, available at https://www.law.cornell.edu/cfr/text/40/80.22.

time savings account for both the reduction over time in the number of vehicles of a given model year that remain in service and the reduction in the number of miles (VMT) driven by those that stay in service. After calculating the absolute value for each regulatory alternative using the methodology and inputs described above, the model calculates the incremental value relative to the baseline as the refueling cost or benefit for that regulatory alternative. More efficient vehicles have to be refueled less often and refueling costs per vehicle decline. In previous rules this was sufficient to account for the majority of any changes in cost of refueling under different CAFE standards as the modelling permitted, since the volumes of new vehicles and existing vehicles on the road was assumed to be constant under all possible standards. However, when sales and scrappage models are included the distribution of new and vehicles varies and a different number of miles will be driven by new and used vehicles in each regulatory alternative.

(c) Including the Legacy Fleet

Under more stringent regulatory alternatives, more miles will be driven by older and less efficient vehicles, and the effect is to reduce or eliminate any refueling benefit from increasing the fuel efficiency of new vehicles. Failing to include the existing fleet makes the costs of refueling artificially lower under more stringent standards because new vehicle sales are lower and not only because new vehicles are more efficient. This update to the calculation of the absolute refueling costs corrects this oversight present in the NPRM cost-benefit analysis by calculating fleet-wide absolute refueling costs before considering the incremental change relative to the baseline.

For other portions of the CAFE model, we track the legacy vehicles by body style and vintage, using average measures for fuel economy, horsepower and curb weight. To estimate refueling costs for these vehicles, we need measures of average fuel tank sizes by body style and vintage. The agencies are unaware of any data that directly estimates this value, but an estimate can be derived from publicly available data on fuel tank sizes of 17 high-volume nameplates with long histories. We average the tank sizes by body style and use these historical values as estimates of the average by body style and vintage. The vehicles included, their fuel tank sizes, and the averages are reported in Table VI-132Table VI-132 through Table VI-134Table VI-134 for cars, vans/SUVs, and pickups, respectively. The averages are used to represent the fuel tank sizes by vintage and vehicle body style. The agencies used the fuel tank sizes from Table VI-130 to Table VI-131 to determine the number of refueling events and time spent refueling to compute refueling costs using the methodology described in the previous section, Section [xxx].

Table VI-132 - Fuel Tank Size of High-Volume Car Models and Averages by Vintage

Model Year	Honda Civic	Honda Accord	Toyota Corolla	Toyota Camry	Ford Mustang	Chevy Corvette	Car Average
1975	10		13.2		12.4	17	**13.2**
1976	10	13.2	13.2		12.4	17	**13.2**
1977	10	13.2	13.2		12.4	17	**13.2**
1978	10.6	13.2	13.2		12.4	24	**14.7**
1979	10.6	13.2	13.2		12.5	24	**14.7**

1980	10.8	13.2	13.2	16.1	12.5	24	**15.0**
1981	10.8	13.2	13.2	16.1	12.5	24	**15.0**
1982	12.2	15.9	13.2	16.1	15.4	24	**16.1**
1983	12.2	15.9	13.2	14.5	15.4	24	**15.9**
1984	12.2	15.9	13.2	14.5	15.4	20	**15.2**
1985	12.2	15.9	13.2	14.5	15.4	20	**15.2**
1986	12.2	15.9	13.2	14.5	15.4	20	**15.2**
1987	12.2	15.9	13.2	15.9	15.4	20	**15.4**
1988	11.9	15.9	13.2	15.9	15.4	20	**15.4**
1989	11.9	15.9	13.2	15.9	15.4	20	**15.4**
1990	11.9	16.9	13.2	15.9	15.4	20	**15.6**
1991	11.9	16.9	13.2	15.9	15.4	20	**15.6**
1992	11.9	16.9	13.2	18.5	15.4	20	**16.0**
1993	11.9	16.9	13.2	18.5	15.4	20	**16.0**
1994	11.9	16.9	13.2	18.5	15.4	20	**16.0**
1995	11.9	16.9	13.2	18.5	15.4	20	**16.0**
1996	11.9	16.9	13.2	18.5	15.4	20	**16.0**
1997	11.9	16.9	13.2	18.5	15.4	19.1	**15.8**
1998	11.9	17.2	13.2	18.5	15.7	19.1	**15.9**
1999	11.9	17.2	13.2	18.5	15.7	19.1	**15.9**
2000	11.9	17.2	13.2	18.5	15.7	18.5	**15.8**
2001	13.2	17.2	13.2	18.5	15.7	18.5	**16.1**
2002	13.2	17.2	13.2	18.5	15.7	18.5	**16.1**
2003	13.2	17.2	13.2	18.5	15.7	18.5	**16.1**
2004	13.2	17.2	13.2	18.5	15.7	18	**16.0**
2005	13.2	17.2	13.2	18.5	16.6	18	**16.1**
2006	13.2	17.2	13.2	18.5	16.6	18	**16.1**
2007	13.2	17.2	13.2	18.5	16.6	18	**16.1**
2008	13.2	18.5	13.2	18.5	16.6	18	**16.3**
2009	13.2	18.5	13.2	18.5	16.6	18	**16.3**
2010	13.2	18.5	13.2	18.5	16	18	**16.2**
2011	13.2	18.5	13.2	18.5	16	18	**16.2**
2012	13.2	18.5	13.2	17	16	18	**16.0**
2013	13.2	17.2	13.2	17	16	18	**15.8**
2014	13.2	17.2	13.2	17	16	18.5	**15.9**
2015	13.2	17.2	13.2	17	16	18.5	**15.9**
2016	12.4	17.2	13.2	17	16	18.5	**15.7**

Table VI-133 - Fuel Tank Size of High-Volume Van/SUV Models and Averages by Vintage

Model Year	Jeep Wrangler	Ford Explorer	Jeep Grand Cherokee	Chevy Blazer	Ford Escape	Honda CR-V	Toyota Rav4	SUVs Average
1975				31				**31.0**
1976				31				**31.0**
1977				31				**31.0**
1978				31				**31.0**
1979				31				**31.0**
1980				31				**31.0**
1981				31				**31.0**
1982				31				**31.0**
1983				31				**31.0**
1984				31				**31.0**
1985				31				**31.0**
1986				31				**31.0**
1987	20			31				**25.5**
1988	20			31				**25.5**
1989	20			31				**25.5**
1990	20			31				**25.5**
1991	20	19.3		30				**23.1**
1992	20	19.3		30				**23.1**
1993	20	19.3	23	30				**23.1**
1994	20	19.3	23	30			15.3	**21.5**
1995	20	19.3	23	20			15.3	**19.5**
1996	20	21	23	19			15.3	**19.7**
1997	19	21	23	19		15.3	15.3	**18.8**
1998	19	21	23	19		15.3	15.3	**18.8**
1999	19	21	20.5	19		15.3	15.3	**18.4**
2000	19	21	20.5	19		15.3	15.3	**18.4**
2001	19	21	20.5	19	16	15.3	14.7	**17.9**
2002	19	22.5	20.5	19	16	15.3	14.7	**18.1**
2003	19	22.5	20.5	19	16	15.3	14.7	**18.1**
2004	19	22.5	20.5	19	16	15.3	14.8	**18.2**
2005	19	22.5	20.5	19	16.5	15.3	14.8	**18.2**
2006	19	22.5	20.5	22	16.5	15.3	15.9	**18.8**
2007	19	22.5	21.1	22	16.5	15.3	15.9	**18.9**
2008	22.5	22.5	21.1	22	16.5	15.3	15.9	**19.4**
2009	22.5	22.5	21.1	22	16.5	15.3	15.9	**19.4**
2010	22.5	22.5	21.1		16.5	15.3	15.9	**19.0**

2011	22.5	18.6	24.6		17.5	15.3	15.9	**19.1**
2012	22.5	18.6	24.6		17.5	15.3	15.9	**19.1**
2013	22.5	18.6	24.6		15.1	15.3	15.9	**18.7**
2014	22.5	18.6	24.6		15.1	15.3	15.9	**18.7**
2015	22.5	18.6	24.6		15.1	15.3	15.9	**18.7**
2016	22.5	18.6	24.6		15.1	15.3	15.9	**18.7**

Table VI-134 - Fuel Tank Size of High-Volume Pickup Models and Averages by Vintage

Model Year	Ford F150	Dodge Ram	Chevy Silverado	Ford Ranger	Pickups Average
1975	39.2				**39.2**
1976	39.2				**39.2**
1977	39.2				**39.2**
1978	39.2				**39.2**
1979	39.2				**39.2**
1980	37.5				**37.5**
1981	37.5	26			**31.8**
1982	37.5	26			**31.8**
1983	37.5	26		19	**27.5**
1984	37.5	26		19	**27.5**
1985	37.5	26		19	**27.5**
1986	37.5	26		19	**27.5**
1987	37.5	26		19	**27.5**
1988	37.5	26		19	**27.5**
1989	37.5	26		19	**27.5**
1990	37.5	26		19	**27.5**
1991	37.5	26		19	**27.5**
1992	37.5	26		19	**27.5**
1993	37.5	30.5		18.8	**28.9**
1994	37.5	30.5		18.8	**28.9**
1995	37.5	30.5		18.8	**28.9**
1996	37.5	30.5		18.8	**28.9**
1997	30	30.5		18.8	**26.4**
1998	30	30.5		18.5	**26.3**
1999	30	30.5	30	18.5	**27.3**
2000	30	30.5	30	18.5	**27.3**
2001	30	30.5	30	18.5	**27.3**
2002	30	30.5	30	18.5	**27.3**
2003	30	30.5	30	18.5	**27.3**
2004	30	30.5	30	18.5	**27.3**

2005	30	30.5	30	18.5	**27.3**
2006	30	30.5	30	18.5	**27.3**
2007	30	30.5	30	18.5	**27.3**
2008	30	30.5	30	18.5	**27.3**
2009	26	29	30	18.5	**25.9**
2010	26	29	30	18.3	**25.8**
2011	26	29	30	18.3	**25.8**
2012	26	29	30		**28.3**
2013	26	29	30		**28.3**
2014	26	29	30		**28.3**
2015	23	29	30		**27.3**
2016	23	29	30		**27.3**

(d) Including Electric Vehicle Recharging

In addition to adding the refueling costs associated with the "legacy fleet," this update adds the cost to recharge electric vehicles to the total refueling costs. Excluding the time spent recharging ignores a real cost borne by owners of electric vehicles, one which was noted by multiple commenters. For example, Ariel Corp. and VNG.co LLC commented that, "EVs require significant changes in consumer fueling behavior given the need to park at recharging points for long periods of time."[1379]

In order to do so, it is important to first understand how many electric vehicle charging events will require the driver to wait and for how long. The answer to this question depends on the range of the electric vehicle and the length of the trip.[1380] For trips shorter than the range, the driver can recharge the vehicle at times that will not require them to be actively waiting and thus there is no recharging cost. Only for trips where the vehicle is driven more miles than the range will the driver have to stop at mid-trip, a time that is assumed to be inconvenient, to recharge the vehicle at least enough to reach the intended destination.

The agencies use trip data from the National Household Transportation Survey (NHTS) to estimate the frequency and expected length of trips that exceed the range of the electric vehicle technologies in the simulation (200 and 300 mile ranges).

The NHTS data is collected from a representative random sample of U.S. households. The survey collects data on individual trips by mode of transportation. A trip is defined by the starting and ending point for any personal travel, so that vehicle trips will capture any time a car is driven. The survey includes identification numbers for households, individuals, and vehicles, and mode of transportation (including the body style of the vehicle for vehicle trips), and the date of the trip. Although some trips made in the same day may allow for convenient charging in between trips, we assume that travel in the same day exceeding the range will involve the driver waiting for the vehicle to charge. The agencies then sum the total number of miles driven by the

[1379] Ariel Corp. and VNG.co LLC, Comment, NHTSA-2018-0067-7573, at 13.
[1380] While the range of EVs is dependent on a number of factors, such as that grade, acceleration, and weather, the agencies take a conservative approach and assume a best-case scenario.

same vehicle in a single day and assume that charging stations are not conveniently available to the driver in between.

Some of the trips in the NHTS have missing information about the duration or length of the trip; we exclude these trips from the dataset. We then subset the dataset into three body styles—cars, vans/SUVs, and pickups—consistent groupings with how we estimate the VMT schedules and scrappage rates. The agencies exclude data on taxis and rental cars as the body style of the vehicle for these trips is not specified (they make up only 0.3 percent of the dataset, so their exclusion is unlikely to alter the estimate). Table VI-135Table VI-135, below, shows the resulting quantiles of the distribution of daily travel for all vehicles considered in the final dataset. This will include multiple days of travel for the same vehicle if more than one day of trip data is recorded in the NHTS.

Table VI-135 - Distribution of Per-Vehicle Daily Miles by Vehicle Type

Percentile	No. Obs.	0th	25th	50th	75th	100th
Car	113,256	0	8	18	38	1,256
SUVs/Vans	79,260	0	8	18	38	1,425
Pickups	31,733	0	9	20	42	1,343
Rentals	723	0	13	32	91	910
Taxis	1,673	0	3	7	15	422

The data in Table VI-135Table VI-135 shows that excluding taxis and rentals may be the best choice even if we knew their body styles. For taxi trips, we only know how many trips an individual driver makes in a day. The number of trips that the taxi cab itself makes in a day is unknown. As can be seen, the distribution of "daily" travel is to the left for taxis because not all trips for those vehicles are reported. Thus, including these vehicles would incorrectly skew the daily travel rates downwards.

The distribution of trip lengths for rental cars, on the other hand, is generally to the right of trips taken privately-owned vehicles. This is likely because individuals are travelling longer distances when they are on vacation or otherwise out-of-town. It seems likely that individuals renting cars for longer trips will not choose electric vehicles for such temporary travel. Thus, including these trips in the dataset would likely overestimate the number of mid-trip charging events necessary for ordinary travel in a way that will not match what actually occurs.

From the final body style datasets, we are able to calculate two measures that allow for the construction of the value of recharging time. First, we calculate the expected distance between trips that exceed the range of 200-mile and 300-mile BEVs (BEV200 and BEV300, respectively). We calculate this as the quotient of the sum of total miles driven by each individual body style and the total number of trips exceeding the range, as shown below:

$$Charge\ Frequency_{Style,Range} = \frac{\sum_{Trip\ \epsilon\ Style} Trip\ Length}{\sum_{Trip\ \epsilon\ Style}[Trip\ Length > Range]}$$ [1381]

This calculates the expected frequency of enroute recharging events, or the amount of miles traveled per inconvenient recharging event. This is used later used to calculate the total expected time to recharge a vehicle.

The second measure needed to calculate the total expected recharging time is the expected share of miles driven that will be charged in the middle of a trip (causing the driver to wait and lose the value of time). In order to calculate this measure we sum the difference of the trip length and range, conditional on the trip length exceeding the range for each body style. We then divide this figure by the sum of the length of all trips for that body style. See the equation below:

$$Share\ Charged_{Style,Range} = \frac{\sum_{Trip\ \epsilon\ Style}([Trip\ Length > Range] * (Trip\ Length - Range))}{\sum_{Trip\ \epsilon\ Style} Trip\ Length}$$

The calculated frequency of inconvenient charging events and share of miles driven that require the driver to wait for BEV's with 200 and 300-mile ranges are presented in Table VI-136Table VI-136, below. As the table shows, cars are expected to require less frequent inconvenient charges and a smaller share of miles driven will require the driver to charge the vehicle in the middle of a trip. Pickups and vans/SUVs have fairly similar measures, with vans and SUVs requiring slightly more inconvenient charging than pickups.

Table VI-136 - Electric Vehicle Recharging Thresholds by Body Style and Range

Body Style	**Cars**	**Vans/SUVs**	**Pickups**
Miles until mid-trip charging event, BEV200	2,000	1,500	1,600
Miles until mid-trip charging event, BEV300	5,200	3,500	3,800

[1381] The denominator counts the number of inconvenient recharging events by body style. It is not a measurement of VMT.

Share of miles charged mid-trip, BEV200	6%	9%	8%
Share of miles charged mid-trip, BEV300	3%	4%	4%

The measures presented in Table VI-136Table VI-136, above, can be used to calculate the expected time drivers of electric vehicles of a given body style and range will spend recharging at a time that will require them to wait. First we calculate the expected number of refueling events for a vehicle of a given style and range in a given calendar year. This is shown below as the expected miles driven by a vehicle in a given calendar year divided by the charge frequency of a vehicle of that style and range (from Table VI-136Table VI-136).

$$Recharge\ Events_{CY,Veh\ \epsilon\ (Style\ \cup\ Range)} = \frac{Miles_{CY,Veh}}{Charge\ Frequency_{Style,Range)}}$$ [1382]

Next, we calculate the number of miles charged for a vehicle of a given style and range in a specific calendar year. This is the product of the number of miles driven by the vehicle and the share of miles driven that require an inconvenient charge for a vehicle of that style and range (from Table VI-136Table VI-136), as presented below:

$$Miles\ Charged_{CY,Veh\ \epsilon\ (Style\ \cup\ Range)} = Miles_{CY,Veh} * Share\ Charged_{Style,Range}$$

We then calculate the expected time that a driver of an electric vehicle of a given style and range will spend waiting for the vehicle to charge. This is the product of the fixed amount of time it takes to get to the charging station and the number of recharging events plus the quotient of the expected miles that will require inconvenient charging over an input assumption of the rate of which a vehicle of that style and range can be charged in a given calendar year (expressed in units of miles charged per hour). We set the fixed amount of time it takes to get to a charging station equal to the average time it takes for an ICE vehicle to get to a gas station for a refueling event, as discussed above.[1383] This is shown below:

$$Charge\ Time_{CY,Veh\ \epsilon\ (Style\ \cup\ Range)} = (Fixed_{Veh} * Recharge\ Events_{CY,Veh}) + \frac{Miles\ Charged_{CY,Veh}}{Charge\ Rate_{CY,Veh}}$$

The expected time that a driver will wait for their vehicle to charge can then be multiplied by the value of time estimate, as is done with gasoline, diesel, and E85 vehicles (see the section describing the current accounting for refueling time costs above).

[1382] Note that $\sum_{Trip\ \epsilon\ Style} Trip\ Length$ and $Miles_{CY,veh}$ are different values. $Miles_{CY,Veh}$ is the estimated amount of VMT predicted by VMT while $\sum_{Trip\ \epsilon\ Style} Trip\ Length$ is the sum of trips observed by the NHTS study.

[1383] The agencies note that this is a conservative estimate. Gas stations vastly outnumber publicly available recharging stations and are often in more convenient locations.

It is worth a final note to talk about how plug-in hybrids are treated in the modelling (which remains unchanged from the NPRM). Presumably, plug-in hybrids that are taken on a trip that exceeds their electric range will be driven on gasoline and the driver will recharge the battery at a time that is convenient. For this reason, the electric portion of travel should be excluded from the refueling time calculation. The gasoline portion of travel is treated the same as other gasoline vehicles so that when the tank reaches some threshold, the vehicles is assumed to be refueled with the same fixed event time and the same rate of refueling flow.

The NPRM calculation of refueling benefits did not account for the impacts of fleet turnover—specifically the impact on "legacy" fleet vehicles and new electric vehicles. However, when the quantities of vehicles on the road varies between scenarios it becomes important to calculate the refueling costs for all vehicles since fuel economy and tank sizes (and therefore range before refueling) vary with vintage. This updated analysis adds these elements to the calculation of the refueling time and costs and is thus a more accurate estimation of the refueling benefit.

(10) Energy security

By amending existing standards, the final rule is expected to increase domestic consumption of gasoline by a relatively minimal amount relative to the baseline standards finalized in 2012 for EPA, producing a correspondingly small increase in the Nation's demand for crude petroleum, a commodity that is traded actively in a worldwide market. [Text Forthcoming] Although the U.S. accounts for a sufficient (albeit diminishing) share of global oil consumption that the resulting increase in global petroleum demand will exert some upward pressure on worldwide prices, the rule is projected to increase global petroleum demand by let than one percent from 2017 through 2015, so its effects on global prices is likely to be minimal.

U.S. consumption and imports of petroleum products has three potential effects on the domestic economy that are often referred to collectively as "energy security externalities," and increases in their magnitude are sometimes cited as possible social costs of increased U.S. demand for petroleum. First, any increase in global petroleum prices that results from higher U.S. gasoline demand will cause a transfer of revenue to oil producers worldwide from consumers of petroleum products and throughout the world, and not just from domestic buyers of new cars and light trucks, because consumers throughout the world are ultimately subject to the higher global price that results. Although this transfer is simply a shift of resources that produces no change in global economic welfare, the financial drain it produces on the U.S. economy is sometimes cited as an external cost of increased U.S. petroleum consumption, because consumers of petroleum products are unlikely to consider it.

Commented [A383]: REVISE: If energy security is assessed from a U.S. perspective, then higher U.S. demand for oil from this final rule will raise world oil prices (marginally) and result increased payments to foreigners. Increased payments to foreigners would be a cost (assuming the U.S. continues to to be a net oil importer) not a transfer.

As the U.S. approaches self-sufficiency in petroleum production (the nation is expected to become a net exporter of petroleum by 2020), however, this transfer is increasingly *from U.S. consumers of refined petroleum products to U.S. petroleum producers*, so it not only leaves

welfare unaffected, but even ceases to be a financial burden on the U.S. economy.[1384] Nevertheless, uncertainty in the nation's long-term import-export balance makes it difficult to project precisely how these effects might change in response to increased consumption.

Higher U.S. petroleum consumption can also increase domestic consumers' exposure to oil price shocks and thus increase potential costs to all U.S. petroleum users (including those outside the light duty vehicle sector, whose consumption would be unaffected by today's final rule) from possible interruptions in the global supply of petroleum or rapid increases in global oil prices. Because users of petroleum products are unlikely to consider the effect of their increased purchases on these risks, and because these effects may have consequences for the overall health of the economy, their economic value is often cited as an external cost of increased U.S. consumption. Finally, some analysts argue that domestic demand for imported petroleum may also influence U.S. military spending; because the increased cost of military activities would not be reflected in the price paid at the gas pump, this is often alleged to represent a third category of external costs form increased U.S. petroleum consumption.

Commented [A384]: CHANGE AS SHOWN: macroeconomic concerns are a, perhaps the, major part of energy security concerns.

Each of these three costs could rise incrementally as a consequence of increases in U.S. petroleum consumption of the very limited magnitude likely to result from the final rule. This section describes the extent to which each cost is expected to increase as result of this action, whether it represents a significant economic cost (or simply a transfer of resources), and how the agencies have measured each cost and incorporated it into their analysis.

(a) U.S. Petroleum Demand and its Effect on Global Prices

Figure VI-51Figure VI-51 illustrates the effect of the increase in U.S. fuel and petroleum demand anticipated to result from reducing CAFE and CO_2 standards on global demand for petroleum and its market price. The marginal increase in domestic demand can be represented as an outward shift in the U.S. demand curve for petroleum from its position at $D_{US,0}$ with the baseline standards for future model years in effect, to $D_{US,1}$ with the final rule standards replacing them. Because global demand is simply the sum of what each nation would purchase at different prices, the outward shift in U.S. demand causes an identical shift in the global demand schedule, as the figure shows.[1385]

[1384] The United States became a net exporter of oil on a weekly basis several times in late 2019, and EIA's AEO 2019 projects that will do so on a sustained, long-term basis by 2020; see EIA, AEO 2019 Reference Case, Table 21 https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=wttntus2&f=4

[1385] The figure exaggerates the U.S. share of total global consumption, which currently stands at 20 percent, for purposes of illustration.

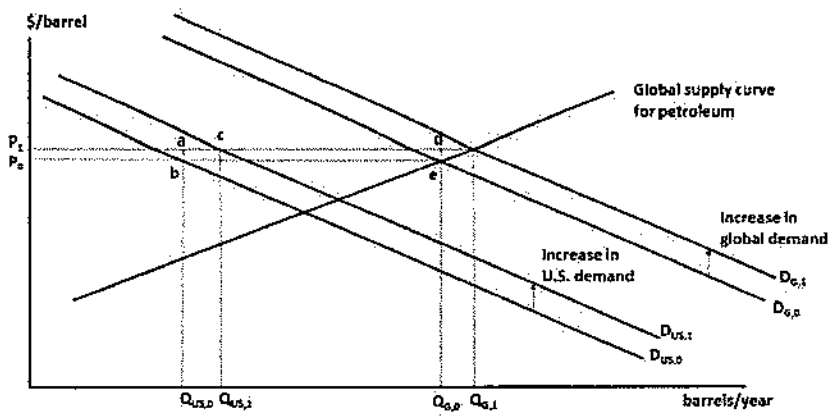

Figure VI-51 - Effect of U.S. Petroleum Demand on Global Prices and Purchases

The global supply curve for petroleum slopes upward, reflecting the fact that it is progressively costlier for oil-producing nations to explore for, extract, and deliver additional supplies of oil to the world market.[1386] Thus the upward shifts in the U.S. and world demand schedules cause an increase in the global price for oil, from P_0 to P_1 in the figure. U.S. purchases of petroleum increase from $Q_{US,0}$ to $Q_{US,1}$, but the resulting increase in global consumption from $Q_{G,0}$ to $Q_{G,1}$ will be slightly smaller than the increase in U.S. demand and purchases, because the amount of petroleum other nations purchase will decline slightly in response to its higher price. Spending on petroleum by U.S. buyers who purchase the additional oil will increase by the area $Q_{US,0}acQ_{US,1}$, the product of its new, higher price P_1 and the increase in U.S. consumption, $Q_{US,1} - Q_{US,0}$, while spending by U.S. consumers whose purchases remain unchanged will increase by the product of their previous purchases $Q_{US,0}$ and the price increase P_1-P_0, or the area P_1abP_0.

CARB asserted in their comments, that the NPRM analysis was biased against the baseline standards because the fuel prices in the NPRM were based on a unique run of DOE's NEMS model that included the baseline.[1387] They argued that the proposal would have reduced

[1386] The figure depicts the relationship between the global supply of petroleum and its worldwide price during a singly time period. The global supply curve for petroleum has been shifting outward over time in response to increased investment in exploration, the ability of refineries to utilize feedstocks other than conventional petroleum, and technological innovations in petroleum extraction. The combination of these developments may also have reduced its upward slope, meaning that global supply now increases by more in response to increases in the world price than it once did.
[1387] NHTSA-2018-0067-11873.

fleet average fuel economy, leading to increased demand and subsequently higher fuel prices faced by consumers. As a result, the additional fuel costs associated with the proposal (relative to the baseline) should have been even higher than estimated because the fuel price faced by drivers in that scenario would have been higher than in the baseline. However, while the difference between the baseline and preferred alternative could create differences in fleet fuel economy in a manner that could influence prices at the pump, those differences are likely to be small. In response to CARB's comments, the agencies conducted additional runs with NEMS to compare the fuel price under the baseline standards and the fuel price under the proposed standards. Through 2050, the fuel price difference between the alternatives was never higher than two percent. The standards being finalized in this rule are considerably closer to the baseline than were those in the proposal.

SAFE commented that the United States is a "price-taker" in the global market and "must accept the prevailing global oil price since it lacks sufficient market power to influence decisively this price."[1388] This comment, however, is directly at odds with both the economics o the world oil market shown in Figure I-1 above and other comments asserting that the increase in U.S. gasoline demand resulting from this rule will increase U.S. and global petroleum demand, thus increasing world oil prices. In response to the comment from SAFE, the agencies applied a forecast of fuel prices in today's analysis that considers the revised standards. This assumption increases the cost of forgone fuel savings in the preferred alternative, relative to the baseline.

Commented [A385]: REVISE: Unless the U.S. itself is the sole buyer & seller of foreign oil, the response given isn't true. Individual purchasers/sellers in the US may be price-takers, yet in aggregate have an effect on world price.

An increase in U.S. oil demand from this final rule would have an impact of world oil prices, albeit a modest price impact. Thus, the U.S. is not viewed as a "price taker" in this case, as SAFE asserts.

In Figure VI-51Figure VI-51, the increase in the price of oil from P_0 to P_1 will mean that global consumers who previously purchased the quantity of oil $Q_{G,0}$ at its lower price will now pay more for that same amount. Specifically, previous purchasers will pay the additional area P_1deP_0, whose value is the increase in price P_1-P_0 multiplied by the volume they originally bought, $Q_{G,0}$. Of this increase in revenue to oil producers, the rectangular area P_1abP_0 – which as indicated above is the product of the increase in price P_1-P_0 and previous U.S. purchases $Q_{US,0}$, and thus measures the increase in spending by previous U.S. consumers – is simply transferred from U.S. consumers to global oil suppliers.[1389] The remaining fraction of increased payments to producers, the rectangular area adeb, whose value is the product of the price increase P_1-P_0 and previous purchases by other nations, which were $Q_{G,0} - Q_{US,0}$, is a transfer from consumers outside the U.S. to global oil producers.

The total increase in global spending – including the additional spending by U.S. consumers as well as by those in other nations - on the amount of oil they previously purchased is simply a transfer of revenue from consumers of petroleum products to oil producers. This transfer can be described as a "pecuniary" externality, since it describes the effect of the price increase on wealth allocation, but is considered separately from any effects on quantity produced and consumed. Some of the increase in payments by U.S. consumers for the petroleum products they originally consumed may be made to foreign-owned oil producers, and thus represents a

[1388] NHTSA-2018-0067-11981.

[1389] Note that global oil suppliers include domestic as well as US-owned foreign suppliers.

financial drain on the U.S. economy, while the remainder is received by domestic producers and thus remains within the U.S. economy.[1390]

To an increasing extent, however, the additional payments by U.S. consumers that result from upward pressure on the world oil price are a transfer *entirely within* the Nation's economy, because a growing fraction of domestic petroleum consumption is supplied by U.S. producers. The U.S. is projected to become a net *exporter* of petroleum in 2020—and in fact became a net exporter in September 2019—and as the Nation moves toward that status, an increasing share of any higher costs paid by U.S. consumers of petroleum products becomes a gain to U.S. oil producers.[1391] When the U.S. becomes self-sufficient in petroleum supply–which is now anticipated to occur in the year this final rule publishes—the *entire* value of increased payments by U.S. petroleum users that results from relaxing CAFE and CO_2 standards will have the same effect as if it were simply a transfer within the U.S. economy. As a consequence, the financial burden that transfers from U.S. consumers to foreign producers places on the U.S. economy will disappear.

Over almost the entire time period spanned by the analysis of this final rule, any increase in domestic spending for petroleum caused by the effect of higher U.S. fuel consumption and petroleum use on world oil prices is expected on balance to be a transfer within the U.S. economy and thus produce no drain on domestic economic resources. For this reason—and because in any case such transfers do not create real economic costs or benefits—increased U.S. spending on petroleum products that results from increased U.S. fuel demand and any resulting upward pressure on petroleum prices stemming from this action is not included among the economic costs accounted for in this final rule.

(b) Macroeconomic Costs of U.S. Petroleum Consumption

In addition to influencing global demand and prices, U.S. petroleum consumption imposes further costs that are unlikely to be reflected in the market price for petroleum, or in the prices paid by consumers of refined products such as gasoline.[1392] Petroleum consumption imposes external economic costs because it exposes the U.S. economy to the risk of rapid increases in prices triggered by global events that may also disrupt the supply of imported oil,

[1390] Neither transfer, however, has an effect on domestic or global economic welfare.

[1391] The U.S. Energy Information Administration EIA estimates that the United States exported more total crude oil and petroleum products in September and October of 2019, and expects the United States to continue to be a net exporter. *See Short Term Energy Outlook November 2019*, available at https://www.eia.gov/outlooks/steo/archives/nov19.pdf.

[1392] *See, e.g.*, Bohi, D. R. & W. David Montgomery (1982), *Oil Prices, Energy Security, and Import Policy* Washington, D.C. - Resources for the Future, Johns Hopkins University Press; Bohi, D. R., & M. A. Toman (1993), "Energy and Security - Externalities and Policies," *Energy Policy* 21:1093-1109; and Toman, M. A. (1993). "The Economics of Energy Security - Theory, Evidence, Policy," in A. V. Kneese and J. L. Sweeney, eds. (1993), *Handbook of Natural Resource and Energy Economics, Vol. III*, Amsterdam - North-Holland, pp. 1167-1218.

and U.S. consumers of petroleum products are unlikely to take such costs into account when making their decisions about how much to consume.

Sudden interruptions in oil supply and rapid increases in its price can impose significant economic costs, because they raise the costs of producing all commodities whose manufacture and distribution consumes petroleum, thus temporarily reducing the level of output that the U.S. economy can produce using its available supplies of labor and capital. The magnitude of any reduction in economic output depends on the extent and duration of the increases in prices for petroleum products that result from a disruption in global oil supplies, as well as on whether and how rapidly prices return to their pre-disruption levels—which in turn depends largely on the rest of the world's capability to respond to interruptions by increasing production elsewhere. Even if prices for oil return completely to their original levels, however, economic output will be at least temporarily reduced from the level that would have been possible with uninterrupted oil supplies and stable prices, so the U.S. economy will bear some transient losses it cannot subsequently recover.

Supply disruptions and price increases caused by global political events tend to occur suddenly and unexpectedly, so they can also force businesses and households to adjust their use of petroleum products more rapidly than if the same price increase occurred gradually. Rapid substitutions between energy derived from oil and other forms of energy, as well as between energy and other inputs, and other changes such as adjusting production levels and downstream prices, can be costly for businesses to make. As with businesses, sudden changes in energy prices and use are also difficult for households to adapt to quickly or smoothly, and doing so may impose at least temporary costs or losses in utility for the various adjustments they make.

Interruptions in oil supplies and sudden increases in petroleum prices are both uncertain prospects, and the costs of the disruptions they can cause must be weighted or adjusted by the probability that they will occur, as well as for their uncertain duration. The agencies estimate this expected cost of such disruptions by combining the probabilities that price increases of different magnitudes and durations will occur during the future period spanned by their analysis with the costs of reduced U.S. economic output and abrupt adjustments to sharply higher petroleum prices. Any *change* in the probabilistic "expected value" of such costs that can be traced to higher U.S. fuel consumption and petroleum demand stemming from this final rule to establish less demanding fuel economy standards is considered to be an external cost of the adopting it.

A variety of mechanisms exist to "insure" against higher petroleum prices and reduce their costs for adjusting to sudden price increases, including making purchases or sales in oil futures markets, adopting energy conservation measures, diversifying the fuel economy levels within the set of vehicles owned by the household, locating where public transit provides a viable alternative to driving, and installing technologies that permit rapid fuel switching. Growing reliance on such measures, coupled with continued improvements in energy efficiency throughout the economy, has certainly reduced the vulnerability of the U.S. economy to the costs of oil shocks in recent decades.

Thus, there is now considerable debate about the magnitude and continued relevance of potential economic damages from sudden increases in petroleum prices. The petroleum intensity of the U.S economy has declined considerably and global oil prices are dramatically lower than when analysts first identified and quantified the risks they create to the U.S. economy. Further, not only has the Nation dramatically increased its own petroleum supply, but other new global supplies have emerged as well, both of which reduce the potential impact of disruptions that occur in unstable or vulnerable regions where oil is produced.

As a consequence, the potential macroeconomic costs of sudden increases in oil prices are now likely to be considerably smaller than when they were originally identified and estimated. Research by the National Research Council (2009) argued that non-environmental externalities associated with dependence on foreign oil are small, and perhaps trivial.[1393] Research by Nordhaus and by Blanchard and Gali have also questioned how harmful to the economy oil price shocks have been, noting that the U.S. economy actually expanded immediately after the most recent oil price shocks, and that there was little evidence of higher energy prices being passed through to higher wages or prices.[1394]

Since these studies were issued in 2009 and 2010, the petroleum intensity of the U.S. economy has continued to decline while domestic energy production has increased in ways and to an extent that experts failed to predict, so that the U.S. became the world's largest producer in 2018.[1395] The U.S. shale oil revolution has both established the potential for energy independence and placed downward pressure on prices. Lower oil prices are also a result of sustained reductions in U.S. consumption and global demand resulting from energy efficiency measures, many undertaken in response to previously high oil prices.

[1393] National Research Council, *Hidden Costs of Energy - Unpriced Consequences of Energy Production and Use*, National Academy of Sciences, Washington, D.C. (2009).

[1394] Nordhaus argues that one reason for limited vulnerability to oil price shocks is that monetary policy has become more accommodating to the price impacts, while another is that U.S. consumers and businesses may determine that such movements are temporary and abstain from passing them on as inflationary price increases in other parts of the economy. He also notes that changes in productivity in response to recent oil price increases are have been extremely modest, observing that "energy-price changes have no effect on multifactor productivity and very little effect on labor productivity." at p. 19. Blanchard and Gali (2010) contend that improvements in monetary policy, more flexible labor markets, and the declining energy intensity of the U.S. economy (combined with an absence of concurrent shocks to the economy from other sources) lessened the impact of oil price shocks after 1980. They find that "the effects of oil price shocks have changed over time, with steadily smaller effects on prices and wages, as well as on output and employment...The message…is thus optimistic in that it suggests a transformation in U.S. institutions has inoculated the economy against the responses that we saw in the past." at p. 414, *See* William Nordhaus, "Who's Afraid of a Big Bad Oil Shock?" Available at http://aida.econ.yale.edu/~nordhaus/homepage/Big_Bad_Oil_Shock_Meeting.pdf; and Blanchard, Olivier and Jordi Gali, J., "The Macroeconomic Effects of Oil price Shocks - Why are the 2000s so Different from the 1970s?," in Gali, Jordi and Mark Gertler, M., eds., *The International Dimensions of Monetary Policy*, University of Chicago Press, February (2010), pp. 373-421, available at http://www.nber.org/chapters/c0517.pdf.

[1395] *See* U.S. Energy Information Administration EIA, *Today in Energy August 20, 2019*, available at https://www.eia.gov/todayinenergy/detail.php?id=40973; *Today in Energy September 12, 2018*, available at https://www.eia.gov/todayinenergy/detail.php?id=37053

Reduced petroleum intensity and higher U.S. production have combined to produce a decline in U.S. petroleum imports—to approximately 20% of domestic consumption in 2017—which permits U.S. supply to act as a buffer against artificial or natural restrictions on global petroleum supplies due to military conflicts or natural disasters. In addition, the speed and relatively low incremental cost with which U.S. oil production has increased suggests that both the magnitude and (especially) the duration of future oil price shocks may be limited, because U.S. production offers the potential for a large and relatively swift supply response.

And while some risk of price shocks certainly still exists, even the potential for a large and swift U.S. production response may be playing a role in limiting the extent of price shocks attributable to external events. The large-scale attack on Saudi Arabia's Abqaiq processing facility—the world's largest crude oil processing and stabilization plant—on September 14, 2019 caused "the largest single-day [crude oil] price increase in the past decade," of between $7 and $8 per barrel, according to EIA.[1396] The Abqaiq facility has the capacity to process 7 million barrels per day, or about 7 percent of global crude oil production capacity. By September 17, only three days later, however, EIA declared

> Saudi Aramco reported that Abqaiq was producing 2 million barrels per day, and they expected its entire output capacity to be fully restored by the end of September. In addition, Saudi Aramco stated that crude oil exports to customers will continue by drawing on existing inventories and offering additional crude oil production from other fields. Tanker loading estimates from third-party data sources indicate that loadings at two Saudi Arabian export facilities were restored to the pre-attack levels. Likely driven by news of the expected return of the lost production capacity, both Brent and WTI crude oil prices fell on Tuesday, September 17.[1397]

Thus, the largest single-day oil price increase in the past decade was largely resolved within a week, and assuming very roughly that average crude oil prices were $70/barrel in September 2019 (slightly higher than actual), an increase of $7/barrel would represent a 10 percent increase as a result of the Abqaiq attack. Contrast this with the 1973 Arab oil embargo, which lasted for months and raised prices 350 percent.[1398] Saudi Arabia could have experienced increased revenue resulting from higher prices following the Abqaiq attack, but instead moved rapidly to restore production and tap reserves to control the risk of resulting price increases. In doing so, the Saudis likely recognized that sustained, long-term price increases would reduce their ability to control global supply (and thus prices and their own revenues) by relying on their lower cost of production.[1399]

[1396] https://www.eia.gov/todayinenergy/detail.php?id=41413

[1397] *Id.*

[1398] *See* Jeanne Whalen, "Saudi Arabia's oil troubles don't rattle the U.S. as they used to," Washington Post, September 19, 2019, available at https://www.washingtonpost.com/business/2019/09/19/saudi-arabias-oil-troubles-dont-rattle-us-like-they-used/.

[1399] *See, e.g.*, "Dynamic Delivery: America's Evolving Oil and Natural Gas Transportation Infrastructure," National Petroleum Council (2019) at 18, available at: https://dynamicdelivery.npc.org/downloads.php.

Some commenters asserted that U.S. shale oil resources cannot serve as "swing supply" to provide stability in the face of a sudden, significant global supply disruption (Jason Bordoff, SAFE).[1400, 1401] Despite its greater responsiveness to price changes, commenters argued that lead time to bring new shale resources to market (6-12 months) is inferior to "true spare capacity" (like Saudi Arabia's large oil fields) because it cannot be deployed quickly enough to mitigate the economic consequences resulting from rapidly rising oil prices. Bordoff, however, also notes that shale oil projects' lead times are still shorter–and possibly much shorter–than conventional oil resource development. So, while new U.S. oil resources may take some time to respond to supply disruptions, they are nevertheless likely to provide a stabilizing influence on supply.

This is especially true for price increases that occur more slowly. When Beccue and Huntington updated their 2005 estimates of supply disruption probabilities in 2016,[1402] they found that the probability distribution was generally flatter–suggesting that supply disruptions of most potential magnitudes were less likely to occur under today's market conditions than they had estimated previously in 2005. In particular, Beccue and Huntington find that supply disruptions of between two and four million barrels per day are significantly less likely than their previous estimates suggested. Although their recent study also estimated that larger supply disruptions (nine or more million barrels per day) are now slightly more likely to occur than in previous estimates, disruptions of that magnitude are extremely unlikely under either set of estimates.

Based on this review of the literature, the agencies concede that shale resources may not be able to stabilize oil markets fully to prevent a price increase associated with a large supply disruption elsewhere in the world. However, if supply disruptions are small enough, or move slowly enough, U.S. resources may be an adequate stabilizer.

The agencies reviewed further research that emphasizes the continued threat to the U.S. economy posed by the potential for sudden increases in global petroleum prices.[1403] For example, Ramey and Vine (2010) note "remarkable stability in the response of aggregate real variables to oil shocks once we account for the extra costs imposed on the economy in the 1970s by price controls and a complex system of entitlements that led to some rationing and shortages."[1404] In contrast, another recent study found that while the likely effects of sudden oil price increases have become smaller over time, the declining sensitivity of petroleum demand to

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[1400] NHTSA-2018-0067-11981.

[1401] NHTSA-2018-0067-10718.

[1402] Beccue, Phillip, Huntington, Hillard, G., 2016. An Updated Assessment of Oil Market Disruption Risks: Final Report. Energy Modeling Forum, Stanford University.

[1403] Hamilton (2012) reviewed the empirical literature on oil shocks and concluded that its findings are mixed, noting that some recent research (*e.g.*, Rasmussen and Roitman, 2011) finds either less evidence for significant economic effects of oil price shocks or declining effects (Blanchard and Gali 2010), while other research finds evidence of their continuing economic importance. *See* Hamilton, J. D., "Oil Prices, Exhaustible Resources, and Economic Growth," *in Handbook of Energy and Climate Change* available at http://econweb.ucsd.edu/~jhamilto/handbook_climate.pdfhttp://econweb.ucsd.edu/~jhamilto/handbook_climate.pdf.

[1404] Ramey, V. A., & Vine, D. J. "Oil, Automobiles, and the U.S. Economy - How Much have Things Really Changed?" National Bureau of Economic Research Working Paper 16067 (June 2010). Available at http://www.nber.org/papers/w16067.pdf.

prices means that any future disruptions to oil supplies will have larger effects on petroleum prices, so that on balance their economic impact is likely to remain significant.[1405]

Some commenters (SAFE, CARB, Fuel Freedom Foundation, IPI) expressed skepticism that the United States could become a net petroleum exporter in the future without the continuation of the baseline standards. They cautioned that the global oil market is inherently uncertain, and Bordoff cautioned that America's shale resources may not last as long, or be as easy to develop, as they currently appear.[1406] If the U.S. does not become a net exporter of petroleum as anticipated, any wealth effects from a high price of oil would continue to accrue to foreign owners of oil reserves. In addition, several of these commenters (CARB, SAFE, Bordoff, Zozana) argued that, regardless of whether or not the U.S. becomes a net petroleum exporter, its levels of petroleum consumption make it still vulnerable to price shocks arising in the global oil market.

The agencies believe that the United States lacks the power (significantly) to control the global oil price and as a consequence remains vulnerable to the effects of to oil price spikes, regardless of our own oil output. Geopolitical factors influence the global oil price—unstable regimes are often unreliable suppliers, large suppliers attempt strategically to manage supply to influence price or retain market share, and international negotiations around politically sensitive topics can influence the production behavior of firms in oil-rich nations. All of these factors, as well as wars and natural disasters, can influence the global supply and the market price for oil.

In this analysis, any increase in the expected value of potential costs from economy-wide disruptions caused by sudden price increases that results from higher U.S. fuel and petroleum demand is accounted for separately from the direct cost for increased purchases of petroleum products. Consumers of petroleum products are unlikely to consider their contributions to these costs when deciding how much energy to consume, because those costs will be distributed widely throughout the economy, falling largely on businesses and households other than those whose decisions impose them. Thus they represent an external (or "social") cost that users of petroleum energy such as transportation fuel are unlikely to internalize fully, and the agencies analysis includes the estimated increase in these costs among of the social costs stemming from the final rule. While increased U.S. petroleum production may impose some limits on their potential magnitude, their underlying source continues to be domestic petroleum *use* rather than imports.

Although the vulnerability of the U.S. economy to oil price shocks depends on aggregate petroleum consumption rather than on the level of oil imports, variation in U.S. oil imports may itself have some effect on the frequency, size, or duration of sudden oil price increases. The expected value of the resulting economic costs would also depend partly on the fraction of U.S. petroleum use that is supplied by imports. While total U.S. petroleum consumption is the primary determinant of potential economic costs to the Nation from rapid increases in oil prices, the estimate of these costs that have been relied upon on in past regulatory analyses—and in this

Commented [A386]: **REVISE:** The primary vulnerability is the shock in oil price, not in oil quantity. And the shock in oil price need not be induced domestically.

[1405] Baumeister, C. and G. Peersman (2012). "The role of time-varying price elasticities in accounting for volatility changes in the crude oil market," *Journal of Applied Econometrics* 28 no. 7, November/December 2013, pp.1087-1109.
[1406] NHTSA-2018-0067-10718.

analysis—is nevertheless expressed per unit (barrel) of *imported* oil. When they are converted to a per-gallon basis, they thus apply to fuel that is either imported in refined form, or refined domestically from imported crude petroleum.

Table VI-137Table VI-137 reports the per-gallon estimates of external costs from potential oil price shocks this analysis uses to estimate the increase in their total value likely to result from this final rule. These values are identical to those used in the recent Draft TAR and in the previous analysis of CAFE and CO_2 standards for model years 2017-2025, except that they have been updated to reflect 2016 prices for this analysis. They depend in part on projected future oil prices, U.S. petroleum consumption and imports, and the total value of petroleum purchases in relation to U.S. economic output (as measured by Gross Domestic Product). Since values were last updated by the agencies for the prior actions mentioned above, all of these factors have evolved in directions that would reduce them, so the figures in Table VI-137Table VI-137 are likely to overestimate the increase in expected costs to the U.S. economy from potential oil price shocks calculated in this analysis, perhaps significantly.[1407, 1408]

Table VI-137 - Change in Expected Cost of Petroleum Price Shocks from Increased Fuel Imports (2016 Dollars per Gallon)

Year	Low	Middle	High
2021	$0.065	$0.142	$0.232
2025	$0.074	$0.159	$0.258
2030	$0.086	$0.183	$0.296
2035	$0.101	$0.214	$0.343
2040	$0.115	$0.243	$0.389
2050	$0.115	$0.243	$0.389

Commented [A387]: **REVISE**: It is not clear where these energy security estimates came from, particularly with the breakout of Low, Middle and High.

Because they are expressed per gallon of fuel that is imported (either in already-refined form, or refined from imported petroleum), applying these estimates requires the agencies to project of any increases in U.S. petroleum and fuel imports that are likely to result from the higher level of fuel consumption anticipated to occur as a result of this final rule. As discussed in detail elsewhere in this final rule, the agencies have elected to retain their previous assumption

[1407] Specifically, the global petroleum prices projected in EIA's Annual Energy Outlook 2018 Reference Case range from 33-57% below those used to develop the estimates reported in Table 8-16. U.S. petroleum consumption and imports are now projected to be 3-8% and 20-27% lower than the forecast values used to construct the estimates in the table. Finally, total petroleum expenditures are now projected to average 1.5-2.4% of U.S. GDP, in contrast to the 3.8-4.0% shares reflected in the values reported in Table 7-16. Each of these differences suggests that the values in Table 8-16 overstate the current magnitude of potential costs to the U.S. economy from the risk of petroleum price shocks, and together they suggest that this overstatement may be significant.

[1408] The costs reported in Table 8-16 also depend on the probabilities or expected frequencies of supply interruptions or sudden price shocks of different sizes and durations. A recent (2016) reassessment of the probabilities on which these estimates are based (which were developed in 2005) concluded that they had not changed significantly 2005, so the values in the table would not have changed for this reason; see Beccue, Phillip C. and Hillard G. Huntington, An Updated Assessment of Oil Market Disruption Risks - Final Report EMF SR 10, Stanford University Energy Modeling Forum (February 5, 2016) available at https://emf.stanford.edu/publications/emf-sr-10-updated-assessment-oil-market-disruption-risks.

that 50 percent of any increase in fuel consumption attributable to its adoption will be imported in refined form. However, they have revised their previous assumption that 90 percent of the remaining increase would be refined domestically from imported petroleum to instead assume that 100 percent of the remaining increase would be refined from imported petroleum.

Commented [A388]: REVISE: What is the basis for the revision from 90 percent to 100 percent of new U.S. oil imports as a result of this final rule would be refined domestically?

Potential Effects of Fuel Consumption and Petroleum Imports on U.S. Military Spending

A third potential effect of increasing U.S. demand for petroleum is an increase in U.S. military spending to secure the supply of oil imports from potentially unstable regions of the world and protect against their interruption. If an increase in fuel consumption that results from reducing CAFE and CO_2 standards lead to higher military spending to protect oil supplies, this increase in outlays would represent an additional external or social cost of the agencies' action. Such costs could also include increased costs to maintain the U.S. Strategic Petroleum Reserve (SPR), because it is intended to cushion the U.S. economy against disruptions in the supply of imported oil or sudden increases in the global price of oil.

While several commenters argued that current U.S. military expenditures are uniquely attributable to securing U.S. supplies of petroleum from unstable regions of the globe – the Middle East, in particular –should be considered as a cost of this action (CARB, SAFE, Zonana), they seemed to confuse those costs with the *marginal* impact of increased oil consumption (relative to the baseline) on U.S. military activity and its costs. However, the agencies disagree with commenters that incremental changes to domestic consumption of oil for light-duty transportation could meaningfully change the scope or scale of the U.S. Department of Defense mission in the Persian Gulf region. Instead, they side with the Fuel Freedom Foundation, which noted in its comment, "[i]ncrementally decreasing petroleum consumption does not significantly decrease the military spending to protect and ensure its flow around the world."[1409]

SAFE estimated a per-gallon cost of military externalities associated with U.S. dependence on petroleum products, and imported petroleum specifically.[1410] Their low estimate of $0.28/gallon assumes $81 billion per year for protection of the global petroleum supply and divides those costs by the number of gallons consumed by U.S. drivers. In contrast, a similar analysis by Crane, et al, stated, "our analysis addresses the incremental cost to the defense budget of defending the production and transit of oil. It does not argue that a partial reduction of the U.S. dependence on imported oil would yield a proportional reduction in U.S. spending that is focused on this mission. The effect on military cost from such changes in petroleum use would be minimal."[1411] We thus do not believe that any incremental petroleum consumption that may result from this final rule will influence any fraction of U.S. defense spending that can be ascribed to protecting the global oil network.

Eliminating petroleum imports (to both the U.S. and its national security allies) *entirely* might permit the Nation to scale back its military presence in oil-supplying regions of the globe

[1409] NHTSA-2018-0067-12016.
[1410] NHTSA-2018-0067-11981.
[1411] Crane, K., A. Goldthau, M. Toman, T. Light, S. E. Johnson, A. Nader, A. Rabasa, & H. Dogo, *Imported Oil and U.S. National Security*, Santa Monica, CA, The RAND Corporation (2009) available at https://www.rand.org/pubs/monographs/MG838.html.

to the extent that such interventions are driven by narrow concerns for oil production rather than other geopolitical considerations, but there is little evidence that U.S. military activity and spending in those regions have varied over history in respouse to fluctnations in the Nation's oil imports, or are likely to do so over the future period spanned by this analysis. Figure VI-52Figure VI-52 shows that military spending as a share of total U.S. economic activity has gradually declined over the past several decades, and that any temporary—although occasionally major–reversals of this longer-term decline have been closely associated with U.S. foreign policy initiatives or overseas wars.

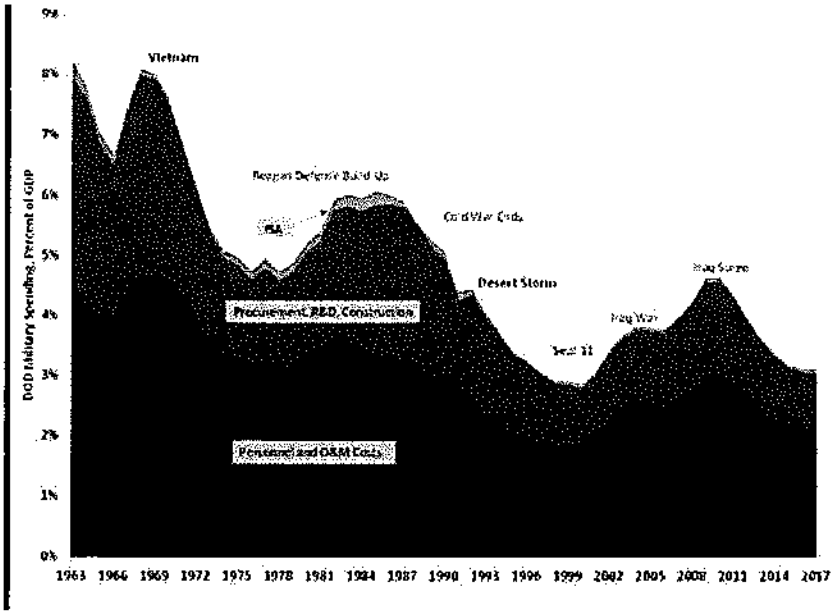

Figure VI-52.- Historical Variation in U.S. Military Spending (% of U.S. Gross Domestic Product)

Figure VI-53Figure VI-53 superimposes U.S. petroleum consnmption and imports on the history of military spending shown in the previous figure. Doing so shows that the decline in U.S military spending throughout most of this period documented in the previous figure coincided with an overall increase in the value of both the Nation's total petroleum purchases and its imports of foreign oil relative to total economic output. This history suggests that U.S. military activities—even in regions of the world that have historically represented vital sources of oil imports–serve a broader range of security and foreign policy objectives than simply protecting oil supplies.

SAFE further argued in its comments that the Americas' involvement in wars in the Persian Gulf region, starting with the first Gulf War and continuing through the Iraq War, has

been a direct consequence of our dependence upon oil. In particular, they state that "[w]hile there is debate over the precise role of oil in America's wars in the greater Middle East, several retired military members of SAFE's ESLC and other defense budget experts that were consulted for this report believe the connection is clear."[1412] However, neither today's action, nor the baseline standards, has the ability to change the historical wealth transfer that created powerful nations in the Middle East. Attributing the cost of the Iraq War, for example, to oil dependence does not directly support an assertion that a marginal reduction in oil dependence could have reduced the cost of that conflict.

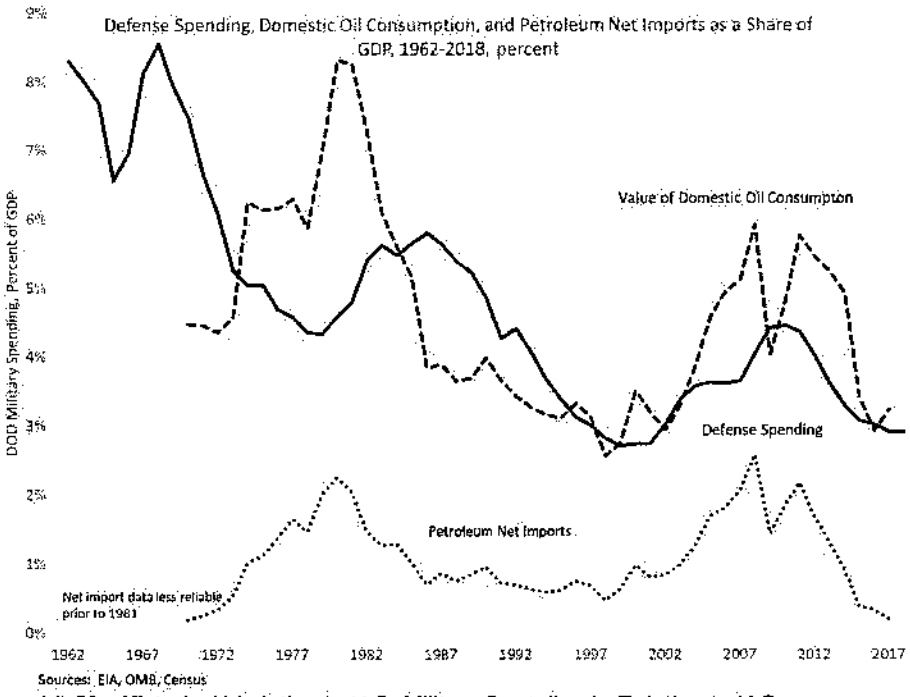

Figure VI-53 - Historical Variation in U.S. Military Spending in Relation to U.S. Petroleum Consumption and Imports (% of U.S. Gross Domestic Product)

Further, the agencies were unable to find a record of the U.S. government attempting to calibrate U.S. military expenditures, force levels, or deployments to any measure of the Nation's petroleum use and the fraction supplied by imports, or to an assessment of the potential

[1412] NHTSA-2018-0067-11981.

economic consequences of hostilities in oil-supplying regions of the world that could disrupt the global market.[1413] Instead, changes in U.S. force levels, deployments, and spending in such regions appear to have been governed by purposeful foreign policy initiatives, unforeseen political events, and emerging security threats, rather than by shifts in U.S. oil consumption or imports.[1414]

The agencies thus conclude that U.S. military activity and expenditures are unlikely to be affected by even relatively large changes in consumption of petroleum-derived fuels by light duty vehicles. Certainly, the historical record offers no suggestion that U.S. military spending is likely to adjust significantly in response to the increase in domestic petroleum use that would result from reducing CAFE and CO_2 standards.

Nevertheless, it is possible that more detailed analysis of military spending might identify some relationship to historical variation in U.S. petroleum consumption or imports. A number of studies have attempted to isolate the fraction of total U.S. military spending that is attributable to protecting overseas oil supplies.[1415] These efforts have produced varying estimates of how much it might be reduced if the U.S. no longer had *any* strategic interest in protecting global oil

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[1413] Crane et al. (2009) analyzed reductions in U.S. forces and associated cost savings that could be achieved if oil security were no longer a consideration in military planning, and disagree with this assessment. After reviewing recent allocations of budget resources they concluded that "…the United States *does* include the security of oil supplies and global transit of oil as a prominent element in its force planning" at p. 74 (emphasis added). Nevertheless, their detailed analysis of individual budget categories estimated that even eliminating the protection of foreign oil supplies *completely* as a military mission would reduce the current U.S. defense budget by approximately 12-15%. *See* Crane, K., A. Goldthau, M. Toman, T. Light, S. E. Johnson, A. Nader, A. Rabasa, & H. Dogo, *Imported Oil and U.S. National Security*., Santa Monica, CA, The RAND Corporation (2009) available at https://www.rand.org/pubs/monographs/MG838.html.

[1414] Crane et al. (2009) also acknowledge the difficulty of reliably allocating U.S. military spending by specific mission or objective, such as protecting foreign oil supplies. Moore et al. (1997) conclude that protecting oil supplies cannot be distinguished reliably from other strategic objectives of U.S. military activity, so that no clearly separable component of military spending to protect oil flows can be identified, and its value is likely to be near zero. Similarly, the U.S. Council on Foreign Relations (2015) takes the view that significant foreign policy missions will remain over the foreseeable future even without any imperative to secure petroleum imports. A dissenting view is that of Stern (2010), who argues that other policy concerns in the Persian Gulf derive from U.S. interests in securing oil supplies, or from other nations' reactions to U.S. policies that attempt to protect its oil supplies. *See* Crane, K., A. Goldthau, M. Toman, T. Light, S.E. Johnson, A. Nader, A. Rabasa, and H. Dogo, *Imported Oil and U.S. National Security*., Santa Monica, CA, The RAND Corporation (2009) available at https://www.rand.org/pubs/monographs/MG838.html; Moore, John L., E.J. Carl, C. Behrens, and John E. Blodgett, "Oil Imports - An Overview and Update of Economic and Security Effects," Congressional Research Service, Environment and Natural Resources Policy Division, Report 98, No. 1 (1997), pp. 1-14; Council on Foreign Relations, "Automobile Fuel Economy Standards in a Lower-Oil-Price World", November 2015; and Stern, Roger J. "United States cost of military force projection in the Persian Gulf, 1976–2007," *Energy Policy* 38, no. 6 (June 2010), pp. 2816-25, https://www.sciencedirect.com/science/article/pii/S0301421510000194?via%3Dihub.

[1415] These include Copulos, M R. "America's Achilles Heel - The Hidden Costs of Imported Oil," Alexandria VA - The National Defense Council Foundation, September 2003 - 1-153, available at http://ndcf.dyndns.org/ndcf/energy/NDCFHiddenCostsofImported_Oil.pdf; Copulos, M R. "The Hidden Cost of Imported Oil--An Update." The National Defense Council Foundation (2007) available at http://ndcf.dyndns.org/ndcf/energy/NDCF_Hidden_Cost_2006_summary_paper.pdf; Delucchi, Mark A. & James J. Murphy. "US military expenditures to protect the use of Persian Gulf oil for motor vehicles," *Energy Policy* 36, no. 6 (June 2008), pp. 2253-64; and National Research Council Committee on Transitions to Alternative Vehicles and Fuels, *Transitions to Alternative Vehicles and Fuels* (2013).

supplies. However, none has identified an estimate of spending that is likely to vary incrementally in response to changes in U.S. petroleum consumption or imports.

Nor have any of these studies tracked changes in spending that can be attributed to protecting U.S. interests in foreign oil supplies over a prolonged period, so they have been unable to examine whether their estimates of such spending vary in response to fluctuations in domestic petroleum consumption or imports. The agencies conclude from this review of research that U.S. military commitments in the Persian Gulf and other oil-producing regions of the world contribute to worldwide economic and political stability, and insofar as the costs of these commitments are attributable to petroleum use, they are attributable to oil consumption throughout the world, rather than simply U.S. oil consumption or imports.

It is thus unlikely that military spending would rise in response to any increase in U.S. imports that did result from this final rule. As a consequence, the analysis of alternative CAFE and CO_2 emission standards for future model years applies no increase in government spending to support U.S. military activities as a potential cost of allowing new cars and light trucks to achieve lower fuel economy and thus increasing domestic petroleum use.

Similarly, while the ideal size of the Strategic Petroleum Reserve from the standpoint of its potential stabilizing influence on global oil prices may be related to the level of U.S. petroleum consumption or imports, its actual size has not appeared to vary in response to either of those measures. The budgetary costs for maintaining the SPR are thus similar to U.S. military spending in that, while they are not reflected in the market price for oil (and thus do not enter consumers' decisions about how much to use), they do not appear to have varied in response to changes in domestic petroleum consumption or imports.

As a consequence, the analysis does not include any potential increase in the cost to maintain a larger SPR among the external or social costs of the increase in gasoline and petroleum consumption likely to result from reducing future CAFE and CO_2 standards. This view aligns with the conclusions of most recent studies of military-related costs to protect U.S. oil imports, which generally conclude that savings in military spending are unlikely to result from incremental reductions in U.S. consumption of petroleum products on the scale of those that would resulting from adopting higher CAFE or CO_2 standards.

(11) Social cost of carbon

In the proposal, the agencies projected costs resulting from fuel consumption and emissions of CO_2 using estimates of anticipated climate-related economic damages within U.S. borders per ton of CO_2 emissions, which we referred to as the domestic social cost of carbon (domestic SC-CO_2). The domestic SC-CO_2 estimates, which were originally developed by EPA for an earlier regulatory analysis, represent the monetary value of damages to the domestic

Commented [A389]: REVISE:
The comments below are duplicate of EPA's comments on the earlier draft section which we sent to NHTSA on 11/22/2019.

EPA suggests using directly modeled SC-CH4 and N2O interim domestic values and include discussion of these estimates along with the SC-CO2 discussion here. For reference, these values and associated text describing their development, use, and application was provided to NHTSA through OMB during the proposal interagency review process.

economy likely to be caused by future changes in the climate that result from incremental increases in CO_2 emissions during a given year.[1416]

These damages include changes in agricultural productivity, adverse effects on human health, property damage from increased flood risk, and changes in costs for managing indoor environments in commercial and residential buildings (such as costs for heating and air conditioning), among other possible damages.

The agencies described the SC-CO_2 estimates used in the NPRM analysis as interim values developed under Executive Order 13783, which are to be used in regulatory analyses until revised values that incorporate recommendations from NAS can be developed.[1417] E.O. 13783 directed agencies to ensure that estimates of the social cost of carbon used in regulatory analyses are consistent with the guidance contained in OMB Circular A-4, "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates."[1418]

Circular A-4 states that analysis of economically significant regulations "should focus on benefits and costs that accrue to citizens and residents of the United States," and the agencies followed this guidance by using estimates of the SC-CO_2 that included only domestic economic damages. In response to Circular A-4's further guidance that regulatory analyses "should provide estimates of net benefits using [discount rates of] both 3 percent and 7 percent," the agencies presented estimates of the proposed rule's economic impacts – including the costs of climate damages likely to result from increased CO_2 emissions – that incorporated both discount rates. The PRIA included a detailed discussion of the analyses used to construct estimates of the domestic SC-CO_2 using these discount rates.[1419]

[1416] For a description of the procedures EPA used to develop these values, see U.S. Environmental Protection Agency, *Regulatory Impact Analysis for the Proposed Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units; Revisions to Emission Guideline Implementing Regulations; Revisions to New Source Review Program*, EPA-452/R-18-006, August 2018 (https://www.epa.gov/sites/production/files/2018-08/documents/utilities_ria_proposed_ace_2018-08.pdf), Section 4.3, pp. 4-2 to 4-7. The sources and potential magnitude of uncertainties surrounding the SC-CO_2 estimates are described in Chapter 7 of that same document, pp. 7-1 to 7-10.

[1417] The guidance followed by EPA in developing the SC-CO_2 values used in the NPRM analysis appears in President of the United States, Executive Order 13783, "Promoting Energy Independence and Economic Growth," March 28, 2017, Federal Register, Vol. 82, No. 61, Friday, March 31, 2017, pp. 16093-16097. (https://www.govinfo.gov/content/pkg/FR-2017-03-31/pdf/2017-06576.pdf) The recommendations of the National Academies are reported in National Academies of Sciences, Engineering, and Medicine, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide*, Washington, D.C., January 2017. Revised values incorporating this guidance have not yet been developed.
https://www.nap.edu/catalog/24651/valuing-climate-damages-updating-estimation-of-the-social-cost-of

[1418] E.O. 13783, p. 16096.

[1419] See NHTSA and EPA, Preliminary Regulatory Impact Analysis: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021 – 2026 Passenger Cars and Light Trucks, July 2018 (updated August 23, 2018, October 16, 2018), Chapter 8, Appendix A.
https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/ld_cafe_co2_nhtsa_2127-al76_epa_pria_181016.pdf.

The estimates of the domestic SC-CO_2 the agencies used in their analysis supporting the proposal increased over future years, partly because emissions during future years are anticipated to contribute larger incremental costs. Future values of the SC-CO_2 also increase because U.S. GDP is growing over time, and many categories of climate-related damage are estimates as proportions of GDP. The agencies' estimates of the domestic SC-CO_2 for emissions occurring in the year 2020 were $1 and $8 (in 2016$) per metric ton of CO_2 emissions using 7 and 3 percent discount rates, and these values were projected to increase to $2 and $10 (again in 2016$) by the year 2050.

As the agencies indicated in the NPRM, the SC-CO_2 estimates are subject to several sources of uncertainty. In accordance with guidance provided by OMB Circular A-4 for treating uncertainty in regulatory analysis, the PRIA included a detailed discussion of how the analysis used to develop the interim SC-CO_2 estimates incorporated sources of uncertainty that could be quantified. It also demonstrated how considering the uncertainty introduced by applying discount rates over extended time horizons could affect the estimated values.[1420] To reflect this uncertainty, the analysis supporting the proposed rule examined the sensitivity of its estimated costs and benefits to using higher values for the SC-CO_2 ($9-14 per metric ton), which were derived using a lower "intergenerational" discount rate of 2.5 percent.[1421]

(a) Comments on the NPRM Value for the SC-CO2

The agencies received extensive comments on the values of the SC-CO_2 used in the NPRM analysis. Broadly, these comments stressed the following concerns:

- Estimating SC-CO_2 domestically systemically underestimates the benefits of stricter standards.
- The agencies' SC-CO_2 omits potential costs due to foreign social and political disruptions caused by climate change that affect the U.S.
- The 7 percent discount rate used in the agencies' main or central analysis is inappropriate because it represents an opportunity cost of capital rather than a rate of time preference for current versus future consumption opportunities, and climate change will affect future consumption.

(b) Domestic vs. Global Value for SC-CO2

Many commenters asserted that it was inappropriate for the agencies to use a domestic SC-CO_2 value for analyzing benefits or costs from changing required levels of fuel economy in the NPRM analysis, primarily because doing so could lead regulatory agencies to adopt measures that provide inadequate reductions in emissions and protection from potential climate change.

As noted in the NPRM and above, the SC-CO_2 estimates the agencies used to estimate climate-related economic costs from adopting less demanding fuel economy and CO_2 emissions were developed in response to the issuance of E.O. 13783. The agencies remind commenters

[1420] See Preliminary RIA, Chapter 8, Appendix A.
[1421] Preliminary Regulatory Impact Analysis, Tables 13-8 and 13-9, pp. 1547-1550.

that E.O. 13783 directed federal agencies to ensure that estimates of the social cost of carbon used in their regulatory analyses are consistent with the guidance contained in OMB Circular A-4, "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates,"[1422] Circular A-4 states that analysis of economically significant proposed and final regulations "should focus on benefits and costs that accrue to citizens and residents of the United States."[1423] The agencies adhered closely to this guidance in evaluating the economic costs and benefits in the proposal and this final rule by using the domestic value of the SC-CO_2 in our central analysis.

Commenters argued that Circular A-4 allows the agencies to use a global SC-CO_2 in their central analysis. For example, IPI et al. commented that "Circular A-4's reference to effects 'beyond the borders' confirms that it is appropriate for agencies to consider the global effects of U.S. greenhouse gas emissions."[1424] While the agencies agree that Circular A-4 allows the agencies to consider foreign impacts in certain circumstances, we disagree that Circular A-4 allows us to use a global SC-CO_2 in our central analysis. Circular A-4 states any non-domestic effects calculated "should be reported separately."[1425] As such, if we had used a global SC-CO_2, we would be compelled by Circular A-4 to separate the SC-CO_2 into domestic and foreign components, and include only the former in our central analysis.

Furthermore, today's analysis will likely have global impacts beyond climate change. For example, freeing manufacturers who compete in the U.S. domestic automobile market from burdensome fuel efficiency standards ~~will~~ may enable them to dedicate time and resources to becoming more competitive in global markets, and is thus likely to affect product innovation and performance throughout the global auto market. It would be inconsistent to report the global SC-CO_2 while ignoring other global costs and benefits. The agencies do not have a method for analyzing the impacts of CAFE and CO_2 standards on a global scale, and did not receive any suggestions about how to conduct such an analysis from commenters. As such, the agencies have decided to focus their attention on domestic impacts, which are more readily measurable.

(c) Scope of Domestic Climate Damages

Some commenters asserted that even if the agencies are required to use a domestic SC-CO_2, the specific value employed by the agencies underestimated the domestic impacts of climate change. They argued the agencies failed to incorporate economic costs associated with social or economic disruptions caused by climate change in regions of the world that were more vulnerable to its effects, but that could "spill over" to impose damages to the U.S. via their effects on migration patterns, international trade flows, or other mechanisms that connect nations. Other commenters argued that E.O. 13783 does not *prohibit* the agencies from using the estimates or practices developed by the IWG to develop new estimates of the SC-CO_2, and

Commented [A390]: REVISE: Circular A-4 states: "Your analysis should focus on benefits and costs that accrue to citizens and residents of the United States. **Where you choose to evaluate a regulation that is likely to have effects beyond the borders of the United States, these effects should be reported separately" (page 15).**

This guidance is relevant to the valuation of damages from CO2 and other GHGs, given that GHGs contribute to damages around the world independent of the country in which they are emitted. Therefore, the final RIA should include estimates of foregone global climate benefits corresponding to the model runs that generated the interim domestic SC-CO2 estimates used in the main analysis.

Commented [A391]: REVISE: EPA does not agree that this should be stated so definitively (that we are not "allowed" to use global SCC values). Also, the statement is inconsistent with the fact that we have used globabl values in the past, so clearly we are "allowed" to.

Commented [A392]: REVISE: EPA disagrees; EPA has in other rules reported the the global values in an appendix to the RIA. As noted in previous comment, given that GHGs contribute to damages around the world independent of the country in which they are emitted (that is they are globally well mixed gases), it is appropriate to evaluate global climate benefits using the global SC-CO2, CH4, and N2O values.

Commented [A393]: REVISE: This statement is contrary to several comments arguing that weakening US standards will make US companies less competitive and cede global leadership (see e.g., MEMA, MECA, NCAT). Thus, this statement should be expanded to provide an alternative viewpoint borne by the comments.

Commented [A394]: REVISE: See comments above – EPA has consistently reported global SC-CO2 values not in the main analysis, but in an appendix to the RIA. This should be done here as well.

[1422] Executive Order 13783, p. 16096.
[1423] *White House Office of Management and Budget*, Circular A-4: Regulatory Analysis, September 17, 2003, p.15. (https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A4/a-4.pdf).
[1424] IPI et al.,
[1425] OMB Circular A-4, p. 15.

asserted that the IWG's methods and resulting estimates continue to represent the best available practices.

However, all of the IWG's estimates measure the global SC-CO_2, while as discussed previously, the agencies ~~are obligated~~have chosen to use a domestic SC-CO_2 and thus ~~were unable to~~ are not relying on the IWG estimates. To develop interim estimates of the domestic SC-CO_2 that were consistent with the IWG's procedures, EPA used the same three climate economic models the IWG employed previously to calculate the domestic SC-CO_2. Two of those three models directly estimate the U.S. domestic SC-CO_2, which represents the economic costs resulting from climate change that are likely to be borne within U.S. borders.[1426] The third model the IWG used previously does not estimate the domestic SC-CO_2 directly, but EPA approximated domestic U.S. costs from future climate change as 10 percent of its estimate of their global value, based on results from a companion model developed by the same author.[1427] Thus the agencies believed that the SC-CO_2 values they used in the NPRM analysis represented the most reliable estimates of domestic economic costs from future climate change that were available for use in evaluating the proposal.

The agencies were unable to develop an estimate of the domestic value for SC-CO_2 that incorporated any of these alleged spillover effects, due both to their speculative nature and to the absence of credible empirical estimates of their potential magnitude. Likewise, commenters did not provide appropriate estimates of these spillovers.

(d) Discount Rate Used to Construct the SC-CO2 Value

Many commenters also objected to the agencies use of an SC-CO_2 value that incorporated a 7 percent discount rate in the NPRM analysis. Some of these comments reflected a misperception that the agencies used such a value in their main or central analysis, when in fact it was only used in a sensitivity analysis case as described below. Other comments appeared to

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The Policy Analysis of the Greenhouse Effect (PAGE) model is described in Hope, C., "The marginal impact of CO_2 from PAGE2002: an integrated assessment model incorporating the IPCC's five reasons for concern," The Integrated Assessment Journal, Vol. 6 No. 1 (2006), pp. 19-56; and Hope, C., "Optimal carbon emissions and the social cost of carbon under uncertainty," The Integrated Assessment Journal Vol. 8, No. 1 (2008), pp. 107-122. The Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) model is documented in Tol, Richard, "Estimates of the damage costs of climate change. Part I: benchmark estimates," and "Estimates of the damage costs of climate change. Part II: dynamic estimates." Environmental and Resource Economics Vol 21 (2002), pp. 47-73 and 135-160.

1427 The third model is the Dynamic Integrated model of Climate and the Economy (DICE), described in Nordhaus, William, "Estimates of the Social Cost of Carbon: Concepts and Results from the DICE-2013R Model and Alternative Approaches." Journal of the Association of Environmental and Resource Economists, Vol. 1, No. 2 (2014), pp. 273-312 (https://www.jstor.org/stable/pdf/10.1086/676035.pdf). The 10 percent figure is based on the results from a regional version of that model (RICE 2010), as described *in* Nordhaus, William D. 2017, "Revisiting the social cost of carbon," Proceedings of the National Academy of Sciences of the United States, 114 (7), pp. 1518-1523, *Table 2*.
(https://pdfs.semanticscholar.org/f83b/3a7431e0ae2d4e8be3d0ee5f3787a802c34c.pdf?_ga=2.211824467.636056015.1572384992-158339427.1562696454).

object to the agencies' use of an SC-CO_2 value incorporating a 7 percent discount rate even as a sensitivity case.

E.O. 13783 directed agencies to ensure that any estimates of the social cost of CO_2 and other greenhouse gases they used for purposes of regulatory analyses are consistent with OMB Circular A-4's guidance "with respect to the consideration of…appropriate discount rates."[1428] In turn, Circular A-4 refers agencies to OMB's earlier guidance on discounting contained in its Circular A-94, noting that "[a]s a default position, OMB Circular A-94 states that a real discount rate of 7 percent should be used as a base-case for regulatory analysis."[1429] OMB continues to use ~~T~~the 7 percent rate ~~continues to represent OMB's~~ to estimate ~~of~~ the average pre-tax rate of return to private capital investment throughout the U.S. economy. Because it is intended to approximate~~s~~ the opportunity cost of capital, it is the appropriate discount rate for evaluating the economic consequences of regulations that affect private-sector capital investments.

Commented [A395]: CHANGE AS SHOWN: OMB Circular A-94, Appendix C, is updated annually. See https://www.federalregister.gov/documents/2018/02/08/2018-02520/discount-rates-for-cost-effectiveness-analysis-of-federal-programs . The most recent provides real interest rates ranging from -0.8% (3-year maturities) to 0.6% (30-year maturities). These are not to be used for regulatory analysis. Circular A-94's values for regulatory analysis come from 1992.

At the same time, however, OMB's guidance on discounting also recognizes that some federal regulations are more likely to affect private consumption decisions made by households and individuals, such as when they affect prices or other attributes of consumer goods. In these cases, Circular A-4 advises that a lower discount rate is likely to be more appropriate, and that a reasonable choice for such a lower rate is the real consumer (or social) rate of time preference. This is the rate at which iadividual consumers discount future consumption to determine its present value to them.

OMB estimate~~d~~s that the rate of consumer time preference ha~~s~~d averaged 3 percent in real or inflation-adjusted terms over an extended period, and continues to ~~do so~~use that value. In summary, Circular A-4 reiterates the guidance provided in OMB's earlier Circular A-94 that "[f]or regulatory analysis, you should provide estimates of net benefits using both 3 percent and 7 percent."[1430]

Commented [A396]: CHANGE AS SHOWN: That value was estimated in 1992 and has not been updated. It's factually true that it's still used, but using the present tense for that value is incorrect.

Finally, OMB's guidance on discounting indicates that it may be appropriate for government agencies to employ an even lower rate of time preference when their regulatory actions entail tradeoffs between improving the welfare of current and future generations. Recognizing this situation, Circular A-4 advises if the "rule will have important intergenerational benefits or costs [an agency] might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent."[1431]

The agencies adhered closely to each of these provisions of OMB's guidance on discounting future climate-related economic costs in their analysis supporting the NPRM. Specifically, their central analysis relied exclusively on a SC-CO_2 value that was constructed by applying a 3 percent discount rate to future climate-related economic damages. This value

[1428] E.O. 13783, p. 16096.
[1429] OMB Circular A-4, p. 33.
[1430] OMB Circular A-4, p. 34.
[1431] OMB Circular A-4, p. 36.

ranged from $6 per metric ton in 2015 to nearly $11 per metric ton (both figures in 2016$) by the end of the analysis period, the year 2050.

Throughout the NPRM central analysis, costs resulting from increased emissions of CO_2 were also discounted from the year when those increases in emissions occurred to the present using a 3percent rate, even when all other future costs and benefits were discounted at a 7 percent rate. Thus the agencies' central analysis for the NPRM did not use SC-CO_2 values for future years that were constructed by applying a 7 percent rate to discount distant future climate-related economic damages, and did not use a 7 percent rate to discount costs of increased CO_2 from the years when they were projected to occur to 2018 (the base year used in the analysis).

Notwithstanding concerns raised by commenters about including a sensitivity analysis that used a higher discount rate, OMB's guidance clearly directs the agencies to report estimates of the present value of the economic costs resulting from increased CO_2 emissions that reflect discount rates of *both* 3 and 7 percent. Thus to supplement their central analysis, which as indicated previously employed a 3 percent discount rate throughout, the agencies also reported an estimate of the economic costs of increased CO_2 emissions based on a value for the SC-CO_2 that was constructed using a 7 percent discount rate as a sensitivity case, which they termed the "Low Social Cost of Carbon" sensitivity analysis.[1432] The values for the SC-CO_2 used in the Low Social Cost of Carbon sensitivity analysis varied from $1 per metric ton in 2015 to $3 per metric ton (both figures in 2016$) by the end of the analysis period. Using these values reduced the loss in total economic benefits resulting from the proposed alternative by 1.1 percent, thus increasing its net benefits by slightly less than 2 percent.[1433]

For the proposal, the agencies also included a second sensitivity analysis using a value for the SC-CO_2 that reflected a lower "intergenerational" discount rate of 2.5 percent, which is within the 1 to 3 percent range for discount rates that have previously been applied to economic costs and benefits that span multiple generations, as reported in OMB guidance.[1434] Because using a lower discount rate results in a higher value for the SC-CO_2, this analysis was termed the "High Social Cost of Carbon" sensitivity case.[1435] The values for the SC-CO_2 used in this additional sensitivity analysis varied from $8 per metric ton in 2015 to $14 per metric ton (both figures in 2016$) in 2050, the last year of the analysis. Using these higher values increased the magnitude of the estimated loss in economic benefits resulted from adopting the proposed rule (versus retaining the Augural standards) by 0.5 percent from that estimated in the central analysis, thus reducing its net benefits by 1.0 percent.[1436] Thus it appeared that when used to

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[1432] Preliminary Regulatory Impact Analysis, Table 13-1, pp. 1531-1534.

[1433] Preliminary Regulatory Impact Analysis, Tables 13-8 and 13-9, pp. 1547-1550. Using a lower value for the SC-CO_2 had opposite effects on the proposal's total and net economic benefits, because its net benefits represented the difference between the loss in benefits and the savings in costs that would result from adopting the proposed rule, compared to the baseline of adopting the Augural standards.

[1434] OMB Circular A-4, p. 36.

[1435] Preliminary Regulatory Impact Analysis, Table 13-1, pp. 1531-1534.

[1436]

construct alternative estimates of the SC-CO_2, the range of discount rates specified in OMB Circular A-4 had little or no effect on the estimated total benefits of the proposed rule, and the sensitivity analyses conducted in support of this Final Rule confirm this result.[1437]

(e) SC-CO2 for the Final Rule

After carefully considering the concerns raised by commenters, the agencies decided to leave the SC-CO_2 values unchanged for the final rule. This means the SC-CO_2 estimate used in this analysis is still a domestic value that was constructed using a 3 percent discount rate, and that costs from increased CO_2 emissions are discounted from the year those emissions occur to the present using a 3 percent rate. The agencies have again included "High Social Cost of Carbon" and "Low Social Cost of Carbon" sensitivity analyses.

Commented [A397]: REVISE: Additionally, the global SC-CO2 values at 3% & 7% should be presented in an appendix.

[Text Forthcoming]

(12) External costs of congestion and noise

(a) Values used to analyze the proposal

As explained in the proposal, changes in vehicle use affect the costs of traffic congestion and highway noise associated with motor vehicle use.[1438] Congestion and noise costs are "external" to the vehicle owners whose decisions about how much, where, and when to drive more—or less—in response to changes in fuel economy result in these costs. Therefore, unlike changes in the costs incurred by drivers for fuel consumption or for safety risks they willingly assume, changes in congestion and noise costs are not offset by corresponding changes in the travel benefits drivers experience.[1439]

Congestion costs are limited to road users; however, since road users include a significant fraction of the U.S. population, changes in congestion costs are treated as part of the rule's economic impact on the broader U.S. economy instead of as a cost or benefit to private parties. Costs resulting from road and highway noise are even more widely dispersed, because they are

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Preliminary Regulatory Impact Analysis, Tables 13-8 and 13-9, pp. 1547-1550. As in the Low Social Cost of Carbon sensitivity case, using a higher value for the SC-CO2 had opposite effects on the total and net economic benefits, because its net benefits were the difference between the sacrifice in benefits and the savings in costs from adopting the proposed rule, where both were measured against the baseline of adopting the Augural standards.

[1437] Need reference to Final Rule sensitivity analyses.

[1438] The proposal estimated changes in congestion and noise costs associated with the overall change in vehicle use, which included changes in the use of new cars and light trucks associated with the fuel economy rebound effect as well as with changes in the use of older vehicles resulting from the effect of CAFE and CO_2 standards on turnover in the car and light truck fleets. As discussed in more detail elsewhere in this final rule, the current analysis assumes that total vehicle use (VMT) differs between the baseline and regulatory alternatives only because of changes in the use of cars and light trucks produced during the model years affected by this rule that occur in response to the fuel economy rebound effect.

[1439] The potential contribution of increased vehicle use to the costs of injuries and property damage caused by motor vehicle crashes may also be partly external to drivers who elect to travel more in response to the fuel economy rebound effect. However, these costs are dealt with directly and in more detail than the external costs of congestion and noise, in section VI.C.2. below.

borne partly by surrounding residents, pedestrians, and other non-road users, and for this reason are also considered as a cost to the U.S. economy as a whole.

To estimate the economic costs associated with changes in congestion and noise caused by differences in miles driven, the analysis supporting the NPRM used estimates of per-mile congestion and noise costs from increased automobile and light truck use that were originally developed by the Federal Highway Administration (FHWA) as part of its 1997 Highway Cost Allocation Study.[1440] The agencies previously employed these same cost estimates in the 2010, 2011, and 2012 final rules.

The marginal congestion cost estimates reported in the 1997 FHWA study were intended to measure the costs of increased congestion resulting from incremental growth in travel by different types of vehicles (including autos and light trucks), and the delays it causes to drivers, passengers, and freight shipments. The study's estimates of marginal noise costs reflected the variation in noise levels resulting from incremental changes in travel by autos, light trucks, and other vehicles, and the annoyance and other adverse impacts caused by noise.

After reviewing the procedures used by FHWA to develop its 1997 marginal cost estimates, considering other available estimates, and noting that commenters had not addressed these costs when they were used in previous rules, the agencies concluded that the FHWA estimates continued to be appropriate for the analysis supporting the proposal. In that analysis, the agencies multiplied FHWA's "middle" estimates of marginal congestion and noise costs per mile of auto and light truck travel in urban and rural areas by the annual increases in driving attributable to the standards to yield increases in total congestion and noise externality costs. Because the proposal, and other alternatives that were considered, reduced the stringency of CAFE and CO_2 standards for model years 2021-2026, resulting in lower fuel economy for new cars and light trucks produced during those years, the fuel economy rebound effect resulted in *fewer* miles driven relative to the baseline, thus generating savings in congestion and noise costs relative to their levels under the baseline. Similarly, each of those alternatives also reduced the total amount of travel by the used vehicle fleet, generating additional savings in these costs.

(b) Comments on the NPRM values

The agencies received few comments on the estimates of congestion and noise costs they used to analyze the economic impacts of the proposal. Almost all of these comments focused on the appropriateness of the estimated magnitude of the fuel economy rebound effect they used to estimate the change in use of new cars and light trucks or the plausibility of the reduction in driving by used vehicles, rather than to the unit costs estimates themselves. These included comments from ICCT and CARB.[1441]

One individual commenter did suggest that recent growth in traffic levels, resulting in part from increased use of home delivery services for online purchases, has increased congestion

[1440] Federal Highway Administration, 1997 Highway Cost Allocation Study, Chapter V, Tables V-22 and V-23, available at https://www.fhwa.dot.gov/policy/hcas/final/five.cfm.
[1441] ICCT, Comment, NHTSA-2018-0067-11741 at 121; CARB, Comment, NHTSA-2018-0067-11873 at 316.

and resulting delays.[1442] Although this commenter is correct, traffic growth is not strictly a recent phenomenon, and longer-term growth in vehicle use—combined with comparatively modest increases in road and highway capacity—has contributed to increasing congestion levels. Because congestion increases more than proportionately to growing traffic volumes, this suggests that FHWA's estimates of congestion costs–now more than two decades old–are likely to understate the contribution of continuing increases in vehicle use to congestion, resulting delays to vehicle occupants and freight shipments, and their associated costs. Because noise levels also increase non-linearly with the volume of traffic using roads and highways, FHWA's 1997 estimates of marginal noise costs may also understate their current values.

(c) Values used to analyze the final rule

In the proposal, the agencies used the FHWA estimates without any adjustments to account for changes since the estimates were published. Recognizing the fact that FHWA's estimates are now more than two decades old, and that some of the data they relied on predated its 1997 study by several years, the agencies attempted to reproduce and update the original calculations FHWA employed to measure the marginal costs of congestion and noise. Unfortunately, the documentation of how these estimates were originally developed was inadequately detailed to enable the agencies to reproduce the calculations, or to support a comprehensive update. Hence, the agencies relied on a more approximate method to update the congestion cost estimate.

The major determinants of marginal congestion costs imposed by additional travel include baseline traffic volumes, which determine current travel speeds and how they would change in response to further increases in travel, together with vehicle occupancy and the value of individuals' travel time. These latter two factors interact to determine the average hourly value of delays to vehicles, by far the largest component of the total cost of delays that occur under congested travel conditions.[1443] Because travel speeds measure the duration of congestion-related delays, while the value of vehicle occupants' time determines their hourly cost, the effects of changes in these variables on overall congestion costs is approximately additive, as long as changes in the two are relatively modest.

The agencies approximated the effect of growth in traffic volumes on travel speeds, congestion-related delays, and congestion costs by increasing FHWA's original estimates using the proportional increase in annual vehicle-miles of travel per lane-mile on major U.S. highways that occurred between 1997 and 2017.

Next, they estimated the proportional increase in the value of travel time per vehicle-hour using the product of growth in the value of travel time per person-hour and the increases in average vehicle occupancy, both measured over the period since the 1997 FHWA study. DOT guidance indicates that growth in individuals' hourly values of travel time is in turn proportional

[1442] Richard Carriere, NHTSA-2018-0067-12216.

[1443] Fuel consumption and other operating costs can also increase during travel in congested conditions, but their relationships to the frequent changes in speed that typically occur in congested travel is less well understood, and in any case they vary by far smaller amounts than the value of vehicle occupants' travel time.

to that in their average hourly wage rates, or the hourly equivalent of household income, depending on the purpose of travel.[1444] The agencies applied the resulting factor to FHWA's original estimate of marginal congestion costs to approximate the increase resulting from growth in the value of vehicle occupants' combined travel time.

After accounting for increased congestion and growth in the value of travel time, the agencies estimate that external congestion costs per additional vehicle-mile of travel by cars and light trucks has more than doubled in real or constant-dollar terms since the publication of the 1997 FHWA cost allocation study.[1445] Adding the effect of price inflation between 1994—the year in which that study's values were originally denominated—and 2018, the adjusted estimates have increased by even more when compared to FHWA's original published values. The updated values of external congestion costs are $0.154 per vehicle-mile of increased travel by cars and $0.138 per vehicle-mile for light trucks (expressed in constant 2018 dollars), and these values are assumed to remain constant throughout the analysis period. The figures compare to values of $0.070 per vehicle-mile for cars and $0.063 per vehicle-mile for light trucks that would have resulted from simply updating the original 1997 FHWA estimates to 2018 dollars. Thus, this update represents a significant change from the values used in previous CAFE analyses, although one that is long overdue.

As indicated previously, the agencies were unable to develop a similar update for the 1997 FHWA estimate of external noise costs resulting from increased car and light truck travel. Thus, the agencies updated the FHWA estimate of marginal noise costs by adjusting for inflation—since the 1994 base year used to express values in the FHWA study—which is consistent with previous CAFE analyses. Because marginal noise costs are so small—less than $0.001 per mile of travel for both cars and light trucks—this change proves to be inconsequential.

(13) Employment assumptions

In previous joint CAFE/CO_2 rulemakings, the agencies considered employment impacts on the automobile manufacturing industry, but many of the considerations were qualitative. In the NPRM, the agencies presented and took comment on a methodology to quantify roughly the direct labor impacts. The agencies recognize there is significant uncertainty in any forward-looking characterization of employment, including effects resulting from CAFE/CO_2 rulemakings. Changes to other policies such as trade policies and tariff policies are likely substantially to alter underlying assumptions presented in the analysis for the rulemaking, and these changes could dwarf any differences between policy alternatives presented. In this section

[1444] *See* U.S. Department of Transportation, Office of the Assistant Secretary for Transportation Policy, Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis, September 27, 2016, pp. 5-6 and Table 1, p. 13.

[1445] The estimated increase is 120 percent in real terms, reflecting the combined effects of a 53 percent increase in traffic volumes relative to roadway capacity (annual vehicle-miles per lane-mile), 22 percent growth in the real or constant-dollar value of travel time per person-hour, and an 18 percent increase in average vehicle occupancy. The exact calculation of the real increase is (1.53*1.22*1.18) - 1 = 1.20, or 120 percent.

the agencies discuss the assumptions made in the NPRM analysis, summarize comments received on that work, and respond to these comments.

(a) Employment baseline (including multiplier effect) and data description

In prior CAFE/CO_2 rulemakings, the agencies considered an analysis of employment impacts in some form in setting both CAFE and tailpipe CO_2 emissions standards; NHTSA conducted an employment analysis in part to determine whether the standards the agency set were economically practicable, that is, whether the standards were "within the financial capability of the industry, but not so stringent as to" lead to "adverse economic consequences, such as a significant loss of jobs or unreasonable elimination of consumer choice."[1446] EPA similarly conducted an employment analysis under the authority granted to the agency under the Clean Air Act.[1447] Both agencies recognized the uncertainties inherent in estimating employment impacts; in fact, both agencies dedicated a substantial amount of discussion to uncertainty in employment analyses in the 2012 final rule for MYs 2017 and beyond.[1448] Notwithstanding these uncertainties, by imposing costs on new light duty vehicles, CAFE and CO_2 standards can have an impact on the demand for labor. Providing the best analysis practicable better informs stakeholders and the public about the standards' impact than would omitting any estimates of potential labor impacts.

The NPRM quantified many of the effects that were previously qualitatively identified, but not considered. For instance, in the PRIA for the 2017-2025 rule EPA identified "demand effects," "cost effects," and "factor shift effects" as important considerations for labor, but the analysis did not attempt to quantify each of these effects.[1449]

The NPRM analysis considered direct labor effects on the automotive sector. The NPRM evaluated how employment in different facets of the automobile manufacturing industry may be affected by the rule, including (1) dealership labor related to new light-duty vehicle unit sales; (2) assembly labor for vehicles, for engines and for transmissions related to new vehicle unit sales; and (3) labor related to mandated additional fuel savings technologies, accounting for new vehicle unit sales. Importantly, this analysis did not consider whether price reductions and regulatory savings associated with different standards would, because price reductions would allow consumers to save or spend that money on other things of value, increase the consumption of other vehicle technologies or, more generally, generate growth in other sectors of the overall economy. This means that the analysis is inherently and artificially narrow in its focus, and does not represent an attempt to quantify the overall labor or economic effects of this rulemaking. All

[1446] 67 FR 77015, 77021 (Dec. 16, 2002).
[1447] *See* George E. Warren Corp. v. EPA, 159 F.3d 616, 623-24 (D.C. Cir. 1998) (ordinarily permissible for EPA to consider factors not specifically enumerated in the Act).
[1448] *See* 77 FR 62624, 62952, 63102 (Oct. 15, 2012).
[1449] U.S. EPA, "Regulatory Impact Analysis: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards," at 8-24 to 8-32 (Aug. 2012).

labor effects were estimated and reported at a national level, in job-years, assuming 2,000 hours of labor per job-year.[1450]

The NPRM analysis estimated labor effects from the forecasted CAFE model technology costs and from review of automotive labor for the MY 2016 fleet. For each vehicle in the CAFE model analysis, the locations for vehicle assembly, engine assembly, and transmission assembly and estimated labor in MY 2016 were recorded. The percent of U.S. content for each vehicle was also recorded.[1451] The analysis also took into account the portion of parts that are made in the U.S. by holding constant the percent of U.S. content for each vehicle as manufacturers add fuel-savings technologies. The analysis further assumes that the U.S. labor added would be proportional to U.S. content, which means that the analysis assumes that U.S. labor inputs would remain constant over time, but this does not reflect a prediction that U.S. labor inputs actually will remain constant.[1452] From this fonndation, the analysis forecasted automotive labor effects as the CAFE model added fuel economy technology and adjusted future sales for each vehicle.

The NPRM analysis also accounted for sales projections in response to the different regulatory alternatives; the labor analysis considers changes in new vehicle prices and new vehicle sales (for further discussion of the sales model, see Section [xxx]). As vehicle prices rise, the analysis expected consumers to purchase fewer vehicles than they would have at lower prices.[1453] As manufacturers sell fewer vehicles, the manufacturers may need less labor to produce the vehicles and dealers may need less labor to sell the vehicles. However, as manufacturers add equipment to each new vehicle, the industry will require labor resources to develop, sell, and produce additional fuel-saving technologies. The analysis also accounted for the possibility that new standards could shift the relative shares of passenger cars and light trucks in the overall fleet (see Section); insofar as different vehicles involved different amounts of labor, this shifting impacts the quantity of estimated labor. The labor analysis took into account the anticipated reduction in vehicle sales, shifts in the mix of passenger cars and light trucks, and addition of fuel-savings technologies that result from the regulation—and, subsequently, the anticipated increase in sales and reduction of fuel-savings technologies that are expected to result from a reduction in stringency.

For the NPRM analysis, the agencies assumed that some observations about the production of MY 2016 vehicles would carry forward, unchanged into the future. For instance, assembly plants would remain the same as MY 2016 for all products now, and in the future. The analysis assumed the percent of U.S. content would remain constant, even as manufacturers updated vehicles and introduced new fuel-saving technologies. The analysis further assumed

[1450] The agencies recognize a few local production facilities may contribute meaningfully to local economies, but the analysis reported only on national effects.

[1451] NHTSA provides reports under 49 CFR Part 583, "American Automobile Labeling Act Reports" with information NHTSA received from vehicle manufacturers about the U.S./Canadian content (by percentage value) of the equipment (parts) used to assemble passenger motor vehicles. *See* https://www.nhtsa.gov/part-583-american-automobile-labeling-act-reports.

[1452] This is a key assumption that should be revisited as trade deals and tax or tariff policies materially change.

[1453] Many commenters contend that higher prices for more efficient goods will have no effect on unit sales and hence necessary production resources and employment. The sales aspect of employment is addressed in the sales section. NHTSA-2018-0067-12000-35, Center for Biological Diversity, et al.

that assembly labor hours per unit would remain at estimated MY 2016 levels for vehicles, engines, and transmissions, and the factor between direct assembly labor and parts production jobs would remain the same. When considering shifts from one technology to another, the analysis assumed revenue per employee at suppliers and original equipment manufacturers would remain in line with MY 2016 levels, even as manufacturers added fuel-saving technologies and realized cost reductions from learning.

The NPRM analysis focused on automotive labor because adjacent employment factors and consumer spending factors for other goods and services are uncertain and difficult to predict. The analysis did not consider how direct labor changes may affect the macro economy and possibly change employment in adjacent industries. For instance, the analysis did not consider possible labor changes in vehicle maintenance and repair, nor did it consider changes in labor at retail gas stations. The analysis did not consider possible labor changes due to raw material production, such as production of aluminum, steel, copper, and lithium, nor did the agencies consider possible labor impacts due to changes in production of oil and gas, ethanol, and electricity. The analysis did not analyze potential labor effects arising from consumption of other products that would not have occurred but for improved fuel economy, nor did the analysis assess the effects arising from reduced consumption of other products that results from more expensive fuel savings technologies at the time of purchase. The effects of increased usage of car-sharing, ride-sharing, and automated vehicles were not analyzed. The analysis did not estimate how changes in labor from any of these industries could affect gross domestic product and possibly affect other industries as a result.

Many commenters voiced concerns that the NPRM analysis only included automotive direct employment, and did not explicitly consider other important factors, and that these factors would be better addressed with a macroeconomic model. For instance, the International Council on Clean Transportation contended that the dollars saved at the pump as a result of fuel saving technologies would be spent elsewhere in the economy, creating jobs.[1454] The Association of Global Automakers also referenced macroeconomic studies that project long-term job gains due to savings at the pump, but also highlight short-term setbacks for jobs as money spent to purchase additional fuel saving technologies on new vehicles is not spent in other job creating sectors of the U.S. economy, which were not considered in an analysis that only addresses direct automotive employment.[1455] The Union of Concerned Scientists and Environmental Defense Fund argued that the modeling of short-term job losses in the macroeconomic models is incorrect, and that purchasing a new vehicle, especially if financed, should *increase* disposable income, because monthly savings at the pump outpace the monthly financed cost of the fuel saving equipment, but also that consumers will not choose this equipment unless a stringent standard is chosen.[1456] The Institute for Policy Integrity commented that an analysis looking only at direct employment is incomplete, and encouraged the agencies to include long-term and economy-wide effects in scope on employment discussions.[1457]

[1454] NHTSA-2018-0067-11741-145, ICCT.
[1455] NHTSA-2018-0067-12032-30, Association of Global Automakers.
[1456] NHTSA-2018-0067-12039-38, Union of Concerned Scientists; NHTSA-2018-0067-12397-4, Environmental Defense Fund, et al.
[1457] NHTSA-2018-0067-12213-66, Institute for Policy Integrity.

The agencies have not quantified employment effects outside of automotive sector direct employment for this final rule. The agencies agree with commenters that the reductions in production costs of new vehicles will free up resources for other productive pursuits. Some producers may shift resources away from the development and production of fuel saving technologies and into the development and production of other vehicle attributes. In this case, there would be a transfer of labor resources within a firm. Other producers may instead pass along the reduction in production costs to consumers in the form of price reductions or avoided price increases, allowing those consumers to allocate those new funds between expenditure in other consumption categories or savings. The increased expenditure in other consumption categories would more efficiently create new employment in sectors expanding to cover new market-based (as opposed to regulatory-based) demand. Increased savings also creates additional investment in new productive capital, which will generate employment opportunities in the future. However, the extent and nature of these effects are all highly uncertain, and the agencies have therefore not quantified the effect of the rule on economy-wide employment in the final rule analysis.

Many commenters expressed concern that America would cede leadership in development and production of fuel saving technologies, and fuel-saving technology investment would be gutted if augural standards were not kept in place. For instance, the Mayor of the City of Chillicothe, and Mayors of other Ohio cities, pointed out that many light duty vehicles are built in Ohio and neighboring geographies, and that workers designing and producing fuel economy equipment make an average annual salary of $61,500, expressing concern that if standards are lowered, some of these jobs may no longer be necessary.[1458] The BlueGreen Alliance pointed out that over the last twenty years, manufacturers have invested billions of dollars into fuel saving technologies, and that multinational companies may shift jobs to other countries if the standards do not require continued, strong, additional investment in even more fuel saving technologies.[1459]

The agencies recognize that development of fuel saving technologies can be capital intensive. However, high fuel economy standards do not, per se, guarantee multinational companies will invest in American research and development or production. For example, the larger percent U.S. content in the MY 2017 light truck vs. the MY 2017 passenger car new vehicle fleet may be tied to the so-called "Chicken Tax," a long-established tariff on the import of light duty trucks.[1460] On average, a light truck in the MY 2017 fleet contained 47.8% U.S. content, while a passenger car contained 36.0% U.S. content. To the extent that other policies encourage multi-national corporations to build and invest in U.S. production facilities, these organizations will need access to capital to do so. Notably, as part of the sales module, as fuel economy of the fleet improves, the agencies assume customers increasingly choose light trucks, meaning that a shift towards light-trucks is already considered in the CAFE model under the augural standards.

Commented [A398]: REVISE: How is this responsive to the above comment that easing the standards will reduce US competitiveness in fuel-saving technologies and its associated jobs?

[1458] NHTSA-2018-0067-12318-2, Mayors of the City of Chillicothe and other Ohio cities.
[1459] NHTSA-2018-0067-12009-6, BlueGreen Alliance.
[1460] On average, a light truck in the MY 2017 fleet contained 47.8% U.S. content, while a passenger car contained 36.0% U.S. content.

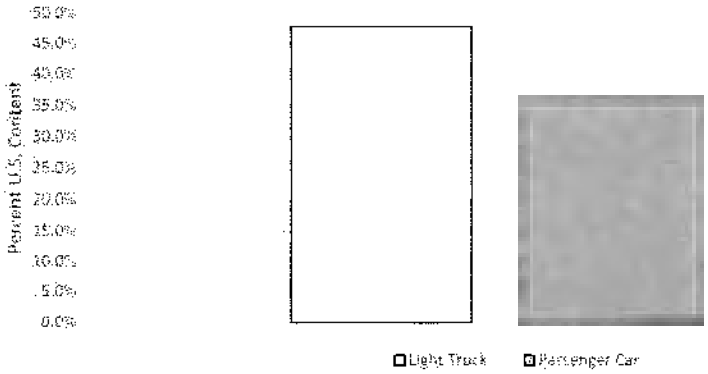

Figure VI-54 – MY 2017 Sales Weighted Percent U.S. Parts Content by Regulatory Class

Finally, no assumptions were made about part-time-level of employment in the broader economy and the availability of human resources to fill positions. When the economy is at full employment, a fuel economy regulation is unlikely to have much impact on net overall U.S. employment; instead, labor would primarily be shifted from one sector to another. These shifts in employment impose an opportunity cost on society, as regulation diverts workers from other market-based activities in the economy. In this situation, any effects on net employment are likely to be transitory as workers change jobs (e.g., some workers may need to be retrained or require time to search for new jobs, while short-term labor shortages in some sectors or regions could result in firms bidding up wages to attract workers). On the other hand, if a regulation comes into effect during a period of less-than-full employment, a change in labor demand due to regulation would affect net overall U.S. employment because the labor market is not in equilibrium. Schmalensee and Stavins point out that net positive employment effects are possible in the near term when the economy is at less than full employment due to the potential hiring of idle labor resources by the regulated sector to meet new requirements (e.g., to install new equipment) and new economic activity in sectors related to the regulated sector longer run.[1461] However, the net effect on employment in the long run is more difficult to predict and will depend on the way in which the related industries respond to regulatory requirements. For that reason, this analysis does not include multiplier effects but instead focuses on labor impacts in the most directly affected industries, which would face the most concentrated labor impacts.

(b) Estimating labor for fuel economy technologies, vehicle components, final assembly, and retailers

The following sections discuss the approaches to estimating factors related to dealership labor, final assembly labor and parts production, and fuel economy technology labor.

[1461] Schmalensee, Richard, and Robert N. Stavins. "A Guide to Economic and Policy Analysis of EPA's Transport Rule." White paper commissioned by Excelon Corporation, March 2011 (Docket EPA-HQ-OAR-2010-0799-0676).

(i) Dealership Labor

The NPRM analysis evaluated dealership labor related to new light-duty vehicle sales, and estimated the labor hours per new vehicle sold at dealerships, including labor from sales, finance, insurance, and management. The effect of new car sales on the maintenance, repair, and parts department labor is expected to be limited, as this need is based on the vehicle miles traveled of the total fleet. To estimate the labor hours at dealerships per new vehicle sold, the agencies referenced the National Automobile Dealers Association 2016 Annual Report, which provides franchise dealer employment by department and function.[1462] The analysis estimated that slightly less than 20% of dealership employees' work relates to new car sales (versus approximately 80% in service, parts, and used car sales), and that on average dealership employees working on new vehicle sales labor for 27.8 hours per new vehicle sold.

The analysis presented today retains assumptions about dealership labor hours per vehicle sold.

(ii) Final assembly labor and parts production

As new vehicle sales increase or decrease, the amount of labor required to assemble parts and vehicles changes accordingly. The NPRM evaluated how the quantity of assembly labor and parts production labor for MY 2016 vehicles would increase or decrease in the future as new vehicle unit sales increased or decreased. Specific assembly locations for final vehicle assembly, engine assembly, and transmission assembly for each MY 2016 vehicle were identified. In some cases, manufacturers assembled products in more than one location, and the analysis identified such products and considered parallel production in the labor analysis.

The analysis estimated average direct assembly labor per vehicle (30 hours), per engine (four hours), and per transmission (five hours) based on a sample of U.S. assembly plant employment and production statistics and other publicly available information. The analysis used the assembly locations and averages for labor per unit to estimate U.S. assembly labor hours for each vehicle. U.S. assembly labor hours per vehicle ranged from as high as 39 hours if the manufacturer assembled the vehicle, engine, and transmission at U.S. plants, to as low as zero hours if the manufacturer imported the vehicle, engine, and transmission.

The analysis also considered labor for parts production. The agencies surveyed motor vehicle and equipment manufacturing labor statistics from the U.S. Census Bureau, the Bureau of Labor Statistics, and other publicly available sources. The agencies found that the historical average ratio of vehicle assembly manufacturing employment to employment for total motor vehicle and equipment manufacturing for new vehicles was roughly constant over the period from 2001 through 2013, at a ratio of 5.26.[1463] Observations from 2001-2013 included many combinations of technologies and technology trends, and many economic conditions, yet the ratio remained about the same over time. Accordingly, the analysis scaled up estimated U.S. assembly labor hours by a factor of 5.26 to consider U.S. parts production labor in addition to

[1462] *NADA Data 2016: Annual Financial Profile of America's Franchised New-Car Dealerships*, National Automobile Dealers Association, https://www.nada.org/2016NADAdata/ (last visited December 20, 2019).
[1463] NAICS Code 3361, 3363.

assembly labor for each vehicle. The estimates for vehicle assembly labor and parts production labor for each vehicle scaled up or down as unit sales scaled up or down over time in the CAFE model.

The analysis presented today retains assumptions about coefficients for final assembly labor and parts production, and updates production and final assembly locations for the MY 2017 fleet.

(iii) Fuel economy technology labor

As manufacturers spend additional dollars on fuel-saving technologies, parts suppliers and manufacturers require labor to bring those technologies to market. Manufacturers may add, shift, or replace employees in ways that are difficult for the agencies to predict; however, it is expected that the revenue per labor hour at original equipment manufacturers (OEMs) and suppliers will remain about the same as in MY 2016 even as manufacturers include additional fuel-saving technology. To estimate the average revenue per labor hour at OEMs and suppliers, the analysis looked at financial reports from publicly traded automotive businesses.[1464] Based on recent figures, it was estimated that OEMs would add one labor year per each $633,066 increment in revenue and that suppliers would add one labor year per $247,648 in revenue.[1465] These global estimates are applied to all revenues, and U.S. content is applied as a later adjustment. In today's analysis, the agencies assume these ratios would remain constant for all technologies rather than that the increased labor costs would be shifted toward foreign countries. There are some reasons to believe that this may be a conservative assumption. For instance, domestic manufacturers may react to increased labor costs by searching for lower-cost labor in other countries. Alternatively, if the new technologies require additional expertise not available overseas, manufacturers may rely more heavily on U.S. parts suppliers with that expertise.

Commented [A399]: REVISE: This approach requires estimates of the effects of the standards on revenues. How were those measured?

Commented [A400]: CHANGE AS SHOWN: Without evidence that one of these scenarios is more likely than the other, it's misleading to show only one.

The analysis presented today retains assumptions about coefficients for fuel economy technology labor, and updates the percent of U.S. content for the MY 2017 fleet.

(iv) Labor Calculations

The agencies estimated the total labor effect as the sum of three components: changes to dealership hours, final assembly and parts production, and labor for fuel-economy technologies (at OEMs and suppliers) that are due to the final rule. The CAFE model calculated additional labor hours for each vehicle, based on current vehicle manufacturing locations and simulation outputs for additional technologies, and sales changes. The analysis applied some constants to

[1464] The analysis considered suppliers that won the Automotive News "PACE Award" from 2013-2017, covering more than 40 suppliers, more than 30 of which are publicly traded companies. Automotive News gives "PACE Awards" to innovative manufacturers, with most recent winners earning awards for new fuel-savings technologies.
[1465] The analysis assumed incremental OEM revenue as the retail price equivalent for technologies, adjusting for changes in sales volume. The analysis assumed incremental supplier revenue as the technology cost for technologies before retail price equivalent mark-up, adjusting for changes in sales volume.

all vehicles.[1466] Other constants were vehicle specific, for all years considered in the analysis.[1467] Still, other constants were year-specific for a vehicle.[1468] While a multiplier effect of all U.S. automotive related jobs on non-auto related U.S. jobs was not considered for the final rule's analysis, the analysis did incorporate a "global multiplier" that can be used to scale up or scale down the total labor hours. This parameter exists in the parameters file, and for the final rule's analysis the analysis set the value at 1.00. These calculations are further discussed in [section xxx] of the Final Regulatory Impact Analysis.

The results of this analysis can be found in Table [Text Forthcoming]. It is important to note, however, that the reduction in job-years described in this table merely reflects the fact that, when compared to the standards set in 2012, fewer jobs will be specifically created to meet ~~infeasible~~ regulatory requirements. It is also important to note that the [xxx] in avoided required technology costs can be invested by manufacturers into other areas, or passed on to consumers or shareholders. Moreover, consumers can either take those cost savings in the form of a reduced vehicle price, or used toward the purchase of specific automotive features that they desire (potentially including a more-efficient vehicle), which would increase employment among suppliers and manufacturers.

Commented [A401]: CHANGE AS SHOWN: Nothing in this analysis finds the standards infeasible.

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2. Simulating safety impacts of regulatory alternatives

The primary objectives of CAFE and CO_2 standards are to achieve maximum feasible fuel economy and reduce CO_2 emissions, respectively, from the on-road light-duty vehicle fleet. In setting standards to achieve these intended effects, the potential of the standards to affect vehicle safety is also considered. As a safety agency, NHTSA has long considered the potential for adverse safety consequences when establishing CAFE standards, and under the CAA, EPA considers factors related to public health and human welfare, including safety, in regulating emissions of air pollutants from mobile sources.

Safety trade-offs associated with fuel economy increases have occurred in the past—particularly before standards were attribute-based—because manufacturers chose to build smaller and lighter vehicles. In cases where fuel economy improvements were achieved through reductions in vehicle size and mass, the smaller, lighter vehicles did not fare as well in crashes as larger, heavier vehicles, on average. Although the agencies now use attribute-based standards, in part to reduce the incentive to downsize vehicles to comply with CAFE and CO_2 standards, the agencies must continue to be mindful of the possibility of safety-related trade-offs.

[1466] The analysis applied the same assumptions to all manufacturers for annual labor hours per employee, dealership hours per unit sold, OEM revenue per employee, supplier revenue per employee, and factor for the jobs multiplier.
[1467] The analysis made vehicle-specific assumptions about percent of U.S. content and U.S. assembly employment hours.
[1468] The analysis estimated technology cost for each vehicle, for each year based on the technology content applied in the CAFE model, year-by-year.

Although prior analyses acknowledged CAFE and CO_2 standards influence factors that affect safety other than vehicle mass, those impacts were not estimated quantitatively.[1469] Instead, the agencies focused exclusively on the safety impacts of changes in vehicle mass. In the proposal, the safety analysis was expanded to include a broader and more comprehensive measure of safety impacts. The final rule retains this comprehensive approach and analyzes the safety impact of three factors:

1) **Changes in Vehicle Mass.** Similar to the previous analyses, the agencies estimate the safety impact of changes in vehicle mass made to reduce fuel consumption and comply with the standards. The agencies' statistical analysis of historical crash data to understand effects of vehicle mass and size on safety indicates reducing mass in heavier vehicles generally improves safety, while reducing mass in lighter vehicles generally reduces safety. NHTSA's crash simulation modeling of vehicle design concepts for reducing mass revealed similar trends.

2) **Impacts of Vehicle Prices.** Vehicles have become safer over time through a combination of new safety regulations and voluntary safety improvements. The agencies expect this trend to continue as new technologies, such as advanced driver assistance systems, are incorporated into new vehicles. Safety improvements will likely continue regardless of changes to CAFE standards. However, the pace of such improvements may be modified if manufacturers choose to delay or forgo investments in safety technology because of the demand CAFE and CO_2 standards impose on scarce research, development, and manufacturing resources.

   As discussed in Chapters [XX and XX], technologies added to comply with fuel economy standards have an impact on vehicle prices, and, by extension, on the affordability impacts of newer, safer vehicles, and therefore on the rate of acquisition of newer vehicles and the rate of retirement of older, less safe vehicles. The delays in fleet turnover caused by sales and scrappage rates impact safety as they slow the penetration of new safety technologies into the fleet.

   Vehicle prices also influence fleet composition. As prices increase, consumers forgo larger, more expensive vehicles. Light trucks have historically had lower fatality rates than passenger cars. Furthermore, vehicles of different body styles have different rates of involvement in fatal crashes, so changing the share of each in the projected future fleet impacts safety.

3) **Increased driving because of better fuel economy.** The "rebound effect" predicts consumers will drive more when the cost of driving declines. More stringent standards reduce vehicle operating costs, and in response, some consumers may choose to drive more. Additional driving increases exposure to risks associated with

[1469] The agencies included a quantification of rebound-associated safety impacts in its Draft TAR analysis, but because the scrappage model is new for this rulemaking, did not include safety impacts associated with the effect of standards on new vehicle prices and thus on fleet turnover. The fact that the scrappage model did not exist prior to this rulemaking does not mean that the effects that it aims to show were not important considerations, simply that the agencies were unable to account for them quantitatively prior to the current rulemaking.

on-road transportation, and this added exposure translates into higher fatalities and injuries.

We measure the impact of these factors through changes in fatalities across the alternatives. Fatalities are calculated, generally, by deriving a societal fatality rate (fatalities per vehicle mile of travel) for the specific factor and multiplying it by the alternative's expected VMT. Fatalities are converted into a societal cost by multiplying fatalities with the value of a statistical life (VSL). As with the NPRM, traffic injuries and property damage are not modeled directly;[1470] rather, traffic injuries and property damage continue to be represented through adjustment factors –as determined by the observed relationships between societal costs of fatalities and societal injury and property damage costs– to fatalities.

All three factors influence predicted fatalities, but only two of them, the changes in vehicle mass and the changes in response to prices—are directly imposed on consumers by CAFE and CO_2 standards. Increased driving associated with rebound is a consumer choice. Greater fuel economy will reduce driving costs, but nothing in the higher CAFE standards compels consumers to drive additional miles. If consumers choose to do so, they are making a decision that the utility of additional driving exceeds the marginal operating costs as well as the perceived added crash risk that additional driving entails. As discussed in [Rebound Safety Section], we account for the voluntary nature of rebound driving by offsetting a portion of the added safety costs.

Commented [A403]: REVISE: The other factor not mentioned here is the change in distribution of driving among vehicles. For example, if standards caused a two-vehicle household to hold rather than replace a vehicle, the relative distribution of driving those two vehicles would be different than for a less stringent standard (due, for example, to the assumed mileage accumulation schedules and holding non-rebound VMT constant). It's difficult to understand why a change in driving distribution caused by delayed scrappage should be treated any differently from the change in driving distribution caused by the rebound effect.

In any case, this change in the driving distribution and associated predicted fatalities are already presented as part of the CAFE model results, so the factor should be described here as well.

Some commenters argued that the agencies should be measuring the change in fatality rate rather than the change in the number of fatalities. For example, EDF argued that changes in fatalities was a measurement of VMT and number of passengers rather than safety, and that "NHTSA's job is to decrease the fatality rate per mile, not to decrease the number of miles people drive."[1471] EDF also commented that the agencies were required to report the "fatality rate data for the overall safety impacts." The agencies disagree with EDF. The agencies are responsible for measuring the impacts of fuel economy and CO_2 standards, including changes to VMT. While other NHTSA safety rules have minimal impacts upon aggregate VMT, CAFE standards have a large impact on VMT and VMT-related costs, including fatalities. It is correct that NHTSA often uses changes in fatality rates as a metric to evaluate the impact of regulations on safety, but these rates are just a tool utilized to derive the relevant safety impact—namely the estimated change in fatalities. Furthermore, as part of the cost-benefit analysis required by Executive Order 12866 and specified in OMB Circular A-4, the agencies must quantify and value safety impacts to compare them to the costs of the regulation. The fundamental metric for valuing loss of life is the VSL. To apply this metric, the agencies must first produce estimates of any change in fatalities that results from the regulatory action. Fatalities prevented, as well as other safety impacts such as non-fatal injuries prevented and property damage crashes avoided, are appropriate measures of rules that affect motor vehicle safety.

Commented [A404]: REVISE: This interpretation of fatality rates as being "just a tool utilized to derive the relevant safety impact" rather than a measure of safety in itself is not consistent with either the statutory definition of the term "vehicle safety" or the common use of the term as a measure of risk.

See 49 USC § 30102(a)(9) "motor vehicle safety" means the performance of a motor vehicle or motor vehicle equipment in a way that protects the public against unreasonable risk of accidents occurring because of the design, construction, or performance of a motor vehicle, and against unreasonable risk of death or injury in an accident, and includes nonoperational safety of a motor vehicle."

[1470] The agencies noted in the NPRM that traffic injuries and property damage are not directly modeled because of insufficient data. *See* PRIA at 43108.
[1471] EDF, Appendix A, NHTSA-2018-0067-12108, at 7-9.

a) Impact of Weight Reduction on Safety

Vehicle mass reduction can be one of the more cost-effective means of increasing fuel economy and reducing CO_2 emissions to meet standards—particularly for makes and models not already built with much high strength steel or aluminum closures or low mass components. Manufacturers have stated that they will continue to reduce vehicle mass to meet more stringent standards, and therefore, this expectation is incorporated into the modeling analysis supporting the standards. Safety trade-offs associated with mass-reduction have occurred in the past, particularly before CAFE standards were attribute-based; past safety trade-offs may have occurred because manufacturers chose at the time, in response to CAFE standards, to build smaller and lighter vehicles. In cases where fuel economy improvements were achieved through reductions in vehicle size and mass, the smaller, lighter vehicles did not fare as well in crashes as larger, heavier vehicles, on average. Although the agencies now use attribute-based standards, in part to reduce or eliminate the incentive to downsize vehicles to comply with CAFE and CO_2 standards,[1472] the agencies must be mindful of the possibility of related safety trade-offs.

Historically, as shown in FARS data analyzed by the agencies, mass reduction concentrated among the heaviest vehicles (chiefly, the largest LTVs, CUVs and minivans) is estimated to reduce overall fatalities, while mass reduction concentrated among the lightest vehicles (chiefly, smaller passenger cars) is estimated to increase overall fatalities. Mass reduction in heavier vehicles is more beneficial to the occupants of lighter vehicles than it is harmful to the occupants of the heavier vehicles. Mass reduction in lighter vehicles is more harmful to the occupants of lighter vehicles than it is beneficial to the occupants of the heavier vehicles. In response to questions of whether designs and materials of more recent model year vehicles may have weakened the historical statistical relationships between mass, size, and safety, we updated our public database for statistical analysis consisting of crash data. The analysis considered the full range of real-world crash types.

The methodology used for the statistical analysis of historical crash data has evolved over many years. The methodology used for the NPRM and unchanged for the final rule reflects learnings and refinements from: NHTSA studies in 2003, 2010, 2011, 2012, and 2016; independent peer review of 23 studies by the University of Michigan Transportation Research Institute;[1473] two public workshops hosted by NHTSA;[1474] interagency collaboration among NHTSA, DOE and EPA; and comments to CAFE and CO_2 rulemakings in 2010, 2012, the 2016 Draft TAR, and the 2018 NPRM. As explained in greater detail below and in FRIA Chapter 11,

[1472] CAFE and CO_2 standards are "footprint-based," with footprint being defined as a measure of a vehicle's size, roughly equal to the wheelbase times the average of the front and rear track widths. Footprint-based standards create a disincentive for manufacturers to produce smaller-footprint vehicles. This is because, as footprint decreases, the corresponding fuel economy/CO_2 emission target becomes more stringent. We also believe that the shape of the footprint curves themselves is such that the curves should neither encourage manufacturers to increase nor decrease the footprint of their fleets.

[1473] Green, Paul E., Kostyniuk, Lidia P., Gordon, Timothy J., and Reed, Matthew P., *Independent Review of Statistical Analyses of Relationship between Vehicle Curb Weight, Track Width, Wheelbase and Fatality Rates*, UMTRI-2011-12, University of Michigan of Transportation Research Institute, 2011, available at http://www.umtri.umich.edu/our-results/publications/independent-review-statistical-analyses-relationship-between-vehicle-curb.

[1474] [add cites]

the methodology used for the statistical analysis of historical crash data for the NPRM and final rule is the best and most up to date available.

Additionally, to assess whether future vehicle designs may impact the relationship of vehicle mass reduction on safety, NHTSA sponsored a fleet crash simulation study using future mass reduction vehicle design concepts (see Section [Text Forthcoming] below). The results of the simulation research showed that future mass reduction techniques continue to exhibit impacts on safety and were consistent with the statistical analysis of FARS crash data. The agencies considered the findings of the study and concluded it was reasonable and appropriate to continue to consider the impact of mass reduction on safety for future vehicles because the data indicate the relationship between mass and safety will continue in the future.

For the rulemaking analysis, the CAFE model tracks the amount of mass reduction applied to each vehicle model as determined in Chapter XX, and then applies estimated changes in societal fatality risk per 100 pounds of mass reduction determined through the statistical analysis of FARS crash data. This process allows the CAFE model to tally changes in fatalities attributed to mass reduction across all of the analyzed future model years. In turn, the CAFE model is able to provide an overall impact of the final standards and alternatives on fatalities attributed to mass reduction.

A number of comments were received on technical aspects of the mass-safety analysis in the NPRM. The agencies carefully considered all comments. Where warranted, the agencies conducted additional analyses to determine whether commenters' suggestions would improve the analysis. The agencies found that the methodology employed by the proposal, which was developed over many years, subject to extensive review and feedback, remains the most rigorous methodology. The agencies found the alternative approaches raised in comments would provide less likely estimates, were statistically problematic, or, in some cases, advocated discarding or ignoring the most likely estimates altogether. The agencies' assessments of comments are discussed in detail in the subsections below.

Overall, consistent with prior analyses, the data show that mass reduction concentrated in heavier vehicles is generally beneficial to overall safety, and mass reduction concentrated in lighter vehicles is harmful.

(1) Crash Data

The agencies use real-world crash data as the basis for projecting the future safety implications for regulatory changes. To support the 2012 rulemaking, NHTSA created a common, updated database for statistical analysis consisting of crash data. The initial iteration contained crash data for model years 2000-2007 vehicles in calendar years 2002-2008. NHTSA made the preliminary version of the new database, which was the basis for NHTSA's 2011 preliminary report (*hereinafter* 2011 Kahane report),[1475] available to the public in May 2011, and

[1475] Kahane, C. J. *Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs – Final Report*, National Highway Traffic Safety Administration (Aug. 2012), available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811665.

an updated version in April 2012 (used in NHTSA's 2012 final report, *hereinafter* 2012 Kahane report),[1476] enabling other researchers to analyze the same data and, hopefully, minimize discrepancies in results caused by reporting inconsistencies across databases.[1477] NHTSA updated the crash and exposure databases for the 2016 Draft TAR analysis.

For the proposed rule and unchanged for today's final rule, the crash and exposure databases were updated again. The databases are the most up-to-date possible (MY 2004-2011 vehicles in CY 2006-2012), given the processing time for crash data and the need for enough crash cases to permit statistically meaningful analyses. As in previous analyses, NHTSA has made the new databases available to the public on its website.[1478]

(2) Methodology

The relationship between a vehicle's mass, size, and fatality risk is complex, and it varies in different types of crashes. We have been examining this relationship for more than two decades. The basic analytical method used to analyze the impacts of weight reduction on safety for the proposal, and unchanged for this final rulemaking, is the same as in 2016 Puckett and Kindelberger report.[1479] NHTSA released the 2016 Puckett and Kindelberger report as a preliminary report on the relationship between fatality risk, mass, and footprint in June 2016 in advance of the Draft TAR. The 2016 Puckett and Kindelberger report covered the same scope as previous NHTSA reports,[1480] offering a detailed description of the crash and exposure databases, modeling approach, and analytical results on relationships among vehicle size, mass, and fatalities that informed the Draft TAR. The modeling approach described in the 2016 Puckett and Kindelberger report was developed with the collaborative input of NHTSA, EPA and DOE, and subject to extensive public review, scrutiny in two NHTSA-sponsored workshops, and a thorough peer review that compared it with the methodologies used in other studies.[1481][1482]

[1476] Kahane, C. J. *Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs – Preliminary Report.* Docket No. NHTSA-2010-0152-0023. Washington, DC: National Highway Traffic Safety Administration.

[1477] *See* 75 FR 25324, 25395-96 (May 7, 2010).

[1478] ftp://ftp.nhtsa.dot.gov/CAFE/2018_mass_size_safety/.

[1479] Puckett, S.M. and Kindelberger, J.C. (2016, June). *Relationships between Fatality Risk, Mass, and Footprint in Model Year 2003-2010 Passenger Cars and LTVs – Preliminary Report.* (Docket No. NHTSA-2016-0068). Washington, DC: National Highway Traffic Safety Administration, available at https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/2016-prelim-relationship-fatalityrisk-mass-footprint-2003-10.pdf

[1480] The 2016 Puckett and Kindelberger report is an extension of 2011 Kahane report and 2012 Kahane report.

[1481] Previous reports from which the 2016 Puckett and Kindelberger report was derived from, were also subject to extensive peer reviews. Farmer, Green, and Lie, who reviewed the 2010 Kahane report, also peer-reviewed the 2011 Kahane report. In preparing his 2012 report (along with the 2016 Puckett and Kindelberger report and Draft TAR), Kahane also took into account Wenzel's assessment of the preliminary report and its peer reviews, DRI's analyses published early in 2012, and public comments such as the International Council on Clean Transportation's comments submitted on NHTSA and EPA's 2010 notice of joint rulemaking. These comments prompted supplementary analyses, especially sensitivity tests, discussed at the end of this section.

[1482] A complete discussion of analyses of vehicle mass and safety considered by the agencies is located in Chapter 11 of the FRIA accompanying this rulemaking.

In computing the impact of changes in mass on safety, the agencies are faced with competing challenges. Research has consistently shown that mass reduction affects "lighter" and "heavier" vehicles differently across crash types. The 2016 Puckett and Kindelberger report found mass reduction concentrated amongst the heaviest vehicles is likely to have a beneficial effect on overall societal fatalities, while mass reduction concentrated among the lightest vehicles is likely to have a detrimental effect on fatalities.[1483] To accurately capture the differing effect on lighter and heavier vehicles, the agencies must split vehicles into lighter and heavier vehicle classifications in the analysis.[1484] However, this poses a challenge of creating statistically-meaningful results. There is limited relevant crash data to use for the analysis. Each partition of the data reduces the number of observations per vehicle classification and crash type, and thus reduces the statistical robustness of the results. The methodology employed by the agencies was designed to balance these competing forces as an optimal trade-off to accurately capture the impact of mass-reduction across vehicle curb weights and crash types while preserving the potential to identify robust estimates.

For the proposal and the final rule, the agencies employed the modeling technique developed in the 2016 Puckett and Kindelberger report to analyze the updated crash and exposure data by examining the cross sections of the societal fatality rate per billion vehicle miles of travel (VMT) by mass and footprint, while controlling for driver age, gender, and other factors, in separate logistic regressions for five vehicle groups and nine crash types. "Societal" fatality rates include fatalities to occupants of all the vehicles involved in the collisions, plus any pedestrians, cyclists, or occupants of other conveyances (e.g., motorcyclists). The agencies utilize the relationships between weight and safety from this analysis, expressed as percentage increases in fatalities per 100-pound weight reduction, to examine the weight impacts applied in this CAFE analysis [as explained in chapter XX]. The effects of mass reduction on safety were estimated relative to (incremental to) the regulatory baseline (augural standards) in the CAFE analysis, across all vehicles for MYs 2018 and beyond.

As in the 2012 Kahane report, 2016 Puckett and Kindelberger report, and the Draft TAR, the vehicles are grouped into three classes: passenger cars (including both two-door and four-door cars); CUVs and minivans; and truck-based LTVs. The curb weight of passenger cars is formulated, as in the 2012 Kahane report, 2016 Puckett and Kindelberger report, and Draft TAR, as a two-piece linear variable to estimate one effect of mass reduction in the lighter cars and another effect in the heavier cars. The boundary between "lighter" and "heavier" cars is 3,201 pounds (which is the median mass of MY 2004-2011 cars in fatal crashes in CY 2006-2012, up from 3,106 pounds for MY 2000-2007 cars in CY 2002-2008 in the 2012 NHTSA safety database, and up from 3,197 pounds for MY 2003-2010 cars in CY 2005-2011 in the 2016 NHTSA safety database). Likewise, for truck-based LTVs, curb weight is a two-piece linear variable with the boundary at 5,014 pounds (again, the MY 2004-2011 median, higher than the median of 4,594 pounds for MY 2000-2007 LTVs in CY 2002-2008 and the median of 4,947

[1483] The findings of the 2016 Puckett and Kindelberger report are consistent with the results of the 2012 Kahane report and Draft TAR.

[1484] If lighter and heavier vehicles are left undistinguished, the agencies analysis would be restricted to identifying a single effect of mass reduction for passenger cars and a single effect of mass reduction for truck-based LTVs. As discussed below, distinct effects have been estimated historically for lighter versus heavier vehicles for cars and LTVs, confirming the validity of distinguishing by curb weight where feasible.

pounds for MY 2003-2010 LTVs in CY 2005-2011). CUVs and minivans are grouped together in a single group covering all curb weights of those vehicles; as a result, curb weight is formulated as a simple linear variable for CUVs and minivans. Historically, CUVs and minivans have accounted for a relatively small share of new-vehicle sales over the range of the data, resulting in less crash data available than for cars or truck-based LTVs. In sum, vehicles are distributed into five groups by class and curb weights: passenger cars < 3,201 pounds; passenger cars 3,201 pounds or greater; truck-based LTVs < 5,014 pounds; truck-based LTVs 5,014 pounds or greater; and all CUVs and minivans.

There are nine types of crashes specified in the analysis for each vehicle group: three types of single-vehicle crashes, five types of two-vehicle crashes; and one classification of all other crashes. Single-vehicle crashes include first-event rollovers, collisions with fixed objects, and collisions with pedestrians, bicycles and motorcycles. Two-vehicle crashes include collisions with: heavy-duty vehicles; cars, CUVs, or minivans < 3,187 pounds (the median curb weight of other, non-case, cars, CUVs and minivans in fatal crashes in the database); cars, CUVs, or minivans ≥ 3,187 pounds; truck-based LTVs < 4,360 pounds (the median curb weight of other truck-based LTVs in fatal crashes in the database); and truck-based LTVs ≥ 4,360 pounds. Grouping partner-vehicle CUVs and minivans with cars rather than LTVs is more appropriate because their front-end profile and rigidity more closely resemble a car than a typical truck-based LTV. An additional crash type includes all other fatal crash types (e.g., collisions involving more than two vehicles, animals, or trains). Splitting the vehicles from this crash type involved in crashes involving two light-duty vehicles into a lighter and a heavier group permits more accurate analyses of the mass effect in collisions of two vehicles.

For a given vehicle class and weight range (if applicable), regression coefficients for mass (while holding footprint constant) in the nine types of crashes are averaged, weighted by the number of baseline fatalities that would have occurred for the subgroup MY 2008-2011 vehicles in CY 2008-2012 if these vehicles had all been equipped with electronic stability control (ESC). The adjustment for ESC, a feature of the analysis added in 2012, takes into account results will be used to analyze effects of mass reduction in future vehicles, which will all be ESC-equipped, as required by NHTSA's safety regulations.

The agencies received multiple comments on how they distribute vehicles into classifications. IPI, quoting a study by Tom Wenzel, commented that sorting vehicles into footprint deciles shows positive impacts from mass reduction for the majority of the footprint deciles.[1485] CARB commented that the agencies should have used the curb weight of all vehicles to calculate the thresholds for "lighter" and "heavier" vehicle types rather than just the curb weights of vehicles involved in fatal crashes.[1486] CARB also commented that pickup trucks and SUVs that are not subject to CAFE regulation (i.e., Class 2b and Class 3 vehicles, such as ¾-ton and one-ton pick-up trucks, vans and related SUVs) should not be included in the assessment of

[1485] IPI, Detailed Comments, Docket No. NHTSA-2018-0067-12213, at 127 (quoting Tom Wenzel, *Assessment of NHTSA's Report "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2004-2011 Passenger Cars and LTVs,"* (LBNL Phase 1, 2018), available at https://escholarship.org/uc/item/4726g6jq).
[1486] CARB, Detailed Comments, Docket No. NHTSA-2018-0067-11873, at 276.

the impact of mass on safety and doing so raises the median weight of trucks.[1487] CARB also commented that the median weights are static values representing the historical fleet, but the median weights and proportions of crash types involving given vehicle weight categories should change with median weight of the fleet modeled by the CAFE model.[1488] Commenters generally believed that the agencies' approach "results in inappropriate apportioning of cars and trucks into the corresponding lighter or heavier bins," which in turn causes the agencies to overestimate the fatalities associated with mass reduction.[1489]

Dividing vehicles into footprint deciles and excluding Class 2b and 3 vehicles pose sample size and data coverage issues. If vehicles were grouped into footprint deciles, the sample sizes in each decile would be approximately one-fifth as large as the corresponding sample sizes in each of the agencies' four passenger car and LTV vehicle classes (and one-tenth as large as the sample size for CUVs and minivans). Smaller parameter estimates require correspondingly smaller standard errors (i.e., relatively precise estimates) to achieve statistical significance, but splitting the limited data into deciles yields larger standard errors, restricting the ability to identify statistically-significant estimates. Likewise, by extending the footprint-curb weight-fatality data to include Class 2b and 3 trucks that are functionally and structurally similar to corresponding ½-ton models that are subject to CAFE regulation,[1490] the sample size and ranges of curb weights and footprint are improved. Sample size is a challenge for estimating relationships between curb weight and fatality risk for individual crash types in the main analysis; dividing the sample further or removing observations makes it exceedingly difficulty to identify meaningful estimates and the relationships that are present in the data.

Commented [A405]: REVISE: It should be noted whether safety regs are the same for these HD vehicles the same as for LD vehicles, are physical aspects like ground clearance typically the same, are they driven in the same manner, etc.?

Compounding the issue is the fact the analysis focuses on societal fatality risk (i.e., all fatalities, including crash partners and people outside of vehicles, such as pedestrians, cyclists, and motorcyclists) rather than merely in-vehicle fatality risk, which yields estimates that are smaller in magnitude (and thus more difficult to identify meaningful differences from zero) than estimates representing changes in in-vehicle fatality risk. That is, compared to an analysis of in-vehicle fatality risk (which would tend to yield relatively large estimated effects of mass reduction), the focus on societal fatalities tends to yield relatively small (net) effects of mass reduction on fatality risk.

[1487] Tom Wenzel of Lawrence Berkeley National Laboratories, Comment, EPA-HQ-OAR-2018-0283-4118, at 1; *see also* CARB, Detailed Comments, Docket No. NHTSA-2018-0067-11873, at 259.
[1488] CARB, Detailed Comments, Docket No. NHTSA-2018-0067-11873, at 260.
[1489] CARB, Detailed Comments, Docket No. NHTSA-2018-0067-11873, at 276.
[1490] Class 2b and 3 pick-up trucks, vans and SUVs have physical characteristics and usage profiles that are substantially similar to their Class 2a counterparts. For example, the Class 2a version of the Ford F-150 has similar physical characteristics to and has a similar usage profile to the Class 2b Ford F150. Same for the Class 2a Ford F150 relative to the Class 2b and 3 Ford F250, and for the GMC Yukon relative to the Yukon XL. Despite being regulated by different fuel economy and emissions regulation as they become heavier, the vehicles may continue to be used in similar ways over time; in turn, the safety implications of the presence of these vehicles may continue to be similar. In contrast, other types of heavy-duty vehicles, such as box trucks, buses, refuse trucks, fire trucks, and other heavy-duty commercial vehicles are substantially different from light duty vehicles in their physical characteristics and usage profiles, and it would not be appropriate to include them in the statistical analysis to determine the impact of mass on crash fatalities.

Including Class 2b and 3 vehicles in the analysis to determine the relationship of vehicle mass on safety has the added benefit of improving correlation constraints. Notably, curb weight increases faster than footprint for large light trucks and Class 2b and 3 pickup trucks and SUVs, in part because the widths of vehicles are constrained more tightly (i.e., due to lane widths) than their curb weights. Including data from Class 2b and 3 pick-up truck and SUV fatal crashes provides data over a wider range of vehicle weights, which improves the ability to estimate the mass-crash fatality relationship. The agencies believe the decision of whether to include Class 2b and 3 vehicles in the analysis should be made based on whether the additional data improves the estimate of the safety impact of mass reduction in light trucks, and that the fatality data should not be simplistically excluded because the vehicles are not regulated under the CAFE and CO_2 emissions programs. Ultimately, the agencies find that: (1) the fundamental objective is to capture the strongest, meaningful signal regarding societal fatality risk as a function of the mass of light trucks; (2) that incorporating information on fatal incidents involving Class 2b and 3 trucks improves the quality of the signal the agencies can capture, and (3) including the vehicles provides the best estimate of the impacts of mass on societal fatalities.

In assessing whether to calculate the median curb weight threshold from all vehicles involved in accidents or on the road, the agencies weighed changing the process used to establish the thresholds and the potential impact on the robustness of the statistical analysis. From a statistical perspective, using thresholds that allocate a similar number of fatal crash cases to both the lower vehicle weight group and the higher vehicle weight group for a given vehicle type will minimize the average standard errors of estimates for both groups, which provides the best estimates for each group. Because reducing average standard errors strengthens the statistical analysis, the agencies conclude using only the curb weight of vehicles involved in fatal crashes to calculate the median curb weight threshold produces the best estimate. This conclusion is the same that was reached previously when considering the same issue for the 2011 Kahane, 2012 Kahane, and 2016 Puckett and Kindelberger analyses.

On a related note, the regression models are estimated based on with respect to the total number of fatalities associated within each vehicle weight group classification (referred to as vehicle group below, for brevity). Shifting the threshold would change the estimated incremental impact of changes in curb weight in each vehicle group, but the net effects would offset each other across vehicle groups, resulting in the same overall estimated effect of changes in vehicle mass on societal fatality risk. For example, if one restricted the "lightest" group for a vehicle type to include only the bottom ten percentiles of vehicle weight, one would expect to identify a very strong detrimental effect (or weakest beneficial effect) of mass reduction for that group. However, the estimated effect of mass reduction in that group has minimal implications for the fleet (i.e., because there are fewer vehicles in the group), and the corresponding estimated effect of mass reduction for other groups would also mute the impact (i.e., because there are many vehicles in the group that vary in mass to a much larger degree than in the "lighter" group). Ultimately, the mean effect of mass reduction across the lighter and heavier groups would be the same as when using the median as the threshold (or at least, similar, subject to limitations in statistical optimization), but with a different point of reference when comparing the groups. Thus, the agencies believe the selection of curb weight threshold has a minimal impact on the estimated effects of mass reduction across all vehicle types.

Full consideration of CARB's comment on mass thresholds, and whether they should change as the median weight of the fleet modeled by the CAFE model changes, requires a deeper look at each of the crash types considered in the analysis. That is, the point estimates presented in

Table VI-138

Table VI-138 represent weighted averages across nine separate, mutually-exclusive and exhaustive crash models (analyzed separately for cars, LTVs, and CUVs and minivans). For example, an individual model for first-event rollovers yields estimates of the percentage change in societal fatality risk per 100-pound mass reduction for lighter and heavier (or, in the case of CUVs and minivans, all) vehicles in the target vehicle class. The final, overall point estimate for a given vehicle type is found by: (1) multiplying the estimate associated with an individual crash type by the estimated share of societal fatalities involving the vehicle class (adjusting for two-vehicle collisions that span vehicle classes to avoid double-counting); and (2) summing the values estimated in (1) across all crash types. In its comments, CARB noted that if the distribution of vehicles in terms of curb weight changes through lightweighting, the shares of (fatal) two-vehicle crashes involving a given pair of vehicles as defined by weight class (e.g., car below a given threshold colliding with a LTV above a given threshold) would change. In turn, the appropriate weighting across the crash types modeled in the analysis would likewise be different (involving an increasing share of vehicles below a given curb weight threshold). Due to these potential limitations, CARB questioned the stability of the summary point estimates relative to changes in the shares of fatalities within each crash type in the analysis.[1491]

To evaluate CARB's concerns regarding future crash mixes and definitions of vehicle weight classes, the agencies performed an exploratory analysis examining the scope and impacts of potential model changes. In doing so, the agencies examined the degree of change in the median vehicle fleet weight in the NPRM analysis relative to the fixed mass threshold values, and also how sensitive the curb weight safety point estimates are to assumptions about the distribution of curb weights in future vehicle fleets. The agencies also considered the feasibility of changing the shares of fatalities by crash type as a function of forthcoming or developing vehicle safety technologies. However, the agencies identified no studies on the effectiveness of forthcoming or developing vehicle safety technologies that could inform projections of shares of fatalities across crash types, nor did the commenters reference any such studies. Likewise, commenters provided no data that would enable projections of these factors. Thus, for a given vehicle mix, the agencies have no information available to justify changing the shares of fatalities across crash types over time. Therefore, the agencies decided to keep the distribution of fatality shares constant for: first-event rollovers; fixed-object collisions; collisions with pedestrians, bicyclists, and motorcycles; collisions with heavy vehicles; collisions with one other light-duty vehicle (i.e., a constant share across the sum of these crashes, but not constant for any given type of crash partner); and all other crashes.

Commented [A406]: REVISE: CARB's comment was basically: "if the proportion of light to heavy pass cars in the fleet changes, then the fatality rates associated with the two groups should change proportionally." Its not clear why "studies on the effectiveness of forthcoming or developing vehicle safety technologies" are necessary, or why fataility rates for collisions with pedestrians can't be adjusted without these.

The agencies had sufficient information to evaluate the effects of changes in the fatal crash mix for cases involving two light-duty vehicles. The agencies agreed that it was internally consistent to adjust fatality shares by crash type proportionally to the distribution of vehicle types and curb weight classes for a given focal MY. An important technical question associated with this approach is the level of disaggregation. The agencies considered an alternative in which the agencies would estimate and apply unique curb weight point estimates for each calendar year in the analysis for each regulatory alternative. This alternative would account for changes in the distribution of crash types associated with changes in both vehicle type shares (i.e., shifts from passenger cars to CUVs and LTVs) and vehicle mass shares (i.e., shifts from vehicles above the

[1491] CARB, Detailed Comments, Docket No. NHTSA-2018-0067-11873, at 278-79.

curb weight thresholds to vehicles below the thresholds). As in the status quo analysis of curb weight and fatality risk, the resulting point estimates would be weighted averages across the individual crash type models as presented in the NPRM, but re-weighted to reflect projected changes to the fleet.

The agencies investigated this alternative and identified several concerns. A key functional constraint is that the curb weight safety point estimates are applied in the CAFE model as a lump-sum, lifetime effect to a given vehicle. This characteristic of the model limits the ability to apply calendar-year-specific effects of changes in curb weight and vehicle type distributions when evaluating safety impacts of changes in curb weights. The safety point estimates also represent net effects of changes in curb weights over the lifetime of a given vehicle in the CAFE model; any changes in the calculation of safety point estimates would need to preserve this characteristic. More broadly, the vehicle fleet is not static over a vehicle's lifetime (i.e., the distributions of curb weight and vehicle type change each year), so the effective probabilities of each crash type over a given vehicle's lifetime are a function of many calendar-year-level curb weight and vehicle type distributions. To capture any effects of changes in vehicle mass distributions over time within the current CAFE model structure, the agencies would need to enact a method that: (1) identifies defensible changes in fatality risk associated with vehicle mass as the distribution of vehicle mass changes (e.g., accounting for changes in the likelihood of observing particular fatal crash types that reflect projected changes in the distribution of vehicle types and curb weights across vehicles); and (2) allocates calendar-year-specific impacts of curb weight on fatality risk to each vehicle in the fleet across the analysis horizon. Identifying how best to achieve this would be complex, and would require the development of an alternative analytical approach that would be outside the scope of this rulemaking.

With these concerns in mind, the agencies explored an alternative approach to test the sensitivity of the safety point estimates to distributions of vehicles by curb weight and vehicle type. The starting point for the alternative approach is maintaining the understanding that the nine crash type models that are present in the curb weight safety analysis represent the best statistical alternatives for evaluating the crash data in the database (i.e., optimal statistical precision conditional on the coverage of the data). Furthermore, the nine crash type models are defined in terms of physical relationships (i.e., crashes involving vehicles of particular curb weight ranges and vehicle types) that are invariant to changes in the distributions of vehicles for those same characteristics. That is, the estimated changes in societal fatality risk as curb weights change for a focal vehicle (i.e., of a particular type and weight range) that is involved in a particular type of crash apply equally to any scenario involving such vehicle, regardless of changes in the probability of observing such a scenario. For example, we would expect the societal fatality risk for a crash involving a passenger car lighter than 3,201 pounds colliding with a LTV heavier than 4,360 pounds to be the same regardless of how many such collisions take place. Thus, we would expect the net effect of a given change in curb weight for a given vehicle type in a given crash type to scale proportionally with the probability of such crashes occurring. Put simply, if there are half as many potential crash partners of a given type in a future year compared to a base year, we would expect a given curb weight reduction to have half as large of a net effect on fatalities in the future year relative to the base year. In the extreme, curb weight changes would have no net effect on fatalities at all for a given crash type if such

Commented [A407]: **REVISE:** "Vehicle type" also includes pass car v. truck v. CUV. Our back-of-the-envelope estimates suggest that the safety impact of fleet sales changes among these categories may far outweigh the effect of mass reduction. This is not taken into account in the main analysis, and it is not taken into account in this sensitivity analysis, despite the implication that it is.

crashes had a zero percent probability of occurring (i.e., if there are no potential crash partner vehicles).

Based on this maintained hypothesis, the agencies examined test curb weight safety point estimates under alternative scenarios, in which fatality shares by crash type were proportional to the distribution of vehicle types and curb weight classes across a range of outcomes reflecting different model years and policy alternatives represented in the NPRM. The sensitivities of the safety point estimates to changes in the distributions of vehicle curb weights and vehicle types were tested by adjusting fatality shares across the relevant crash types in the analysis (i.e., involving two light-duty vehicles) in a manner consistent with potential changes in the vehicle fleet, while holding the outputs of the individual crash type models the same as in the NPRM.

For example, compare the safety point estimate for LTVs lighter than 5,014 pounds in the NPRM with an alternative point estimate for an extreme hypothetical future year where 80 percent of the LTV fleet is lighter than the median curb weight for crash partners (4,360 pounds):

Table VI-138 - Calculation of Example Alternative Safety Point Estimate (LTVs Lighter than 5,014 Pounds)

Crash Type	Share of Fatalities		Change in Fatality Risk per 100-Pound Mass Reduction for Crash Type (%)	Change in Fatalities per 100-Pound Mass Reduction for Crash Type (Baseline = 1,782)	
	NPRM	Example		NPRM	Example
First-Event Rollover	0.03	0.03	0.65	0.3	0.3
Hit Fixed Object	0.11	0.11	-0.53	-1.0	-1.0
Hit Pedestrian/Bicycle/Motorcycle	0.22	0.22	0.78	3.0	3.0
Hit Heavy Vehicle	0.06	0.06	2.10	2.3	2.3
Hit Car/CUV/Minivan < 3,187 Lbs.	0.12	0.12	0.48	1.0	1.0
Hit Car/CUV/Minivan 3,187+ Lbs.	0.12	0.12	-0.46	-1.0	-1.0
Hit Truck-Based LTV < 4,360 Lbs.	0.05	*0.08*	0.54	0.5	0.7
Hit Truck-Based LTV 4,360+ Lbs.	0.04	*0.02*	1.91	1.5	0.7
All Other	0.25	0.25	-0.93	-1.0	-4.1
Total	1.00	1.00	NPRM: 0.31 Example: 0.28	5.5	4.9

The estimated net societal effect of a 100-pound mass reduction is equal to: (1) the sum of the estimated net effects across all crash types, divided by (2) the baseline estimate of annual fatalities involving the vehicle class (adjusted to avoid double-counting) for the most recent four MYs in the database (MYs 2008-2011), or 1,782 fatalities per year. In the NPRM, the estimated net societal effect of a 100-pound mass reduction for lighter LTVs was a 5.5 fatality increase, or a 0.31 percent increase relative to a baseline of 1,782 fatalities. Changing the share of crash fatalities involving heavier LTVs to be consistent with a fleet with only 20 percent of LTVs above the curb weight threshold yields: (1) an increase in incremental fatalities in crashes involving lighter LTVs (from 0.5 fatality to 0.7 fatality); and (2) a decrease in incremental fatalities in crashes involving heavier LTVs (from 1.5 fatalities to 0.7 fatality); for a total net increment of 4.9 fatalities compared to the NPRM's estimate of 5.5 fatalities. Thus, we estimate that, in a future year where the fleet differs from the baseline by having an extreme case of 80 percent of LTVs below the crash-partner curb weight threshold, the net societal effect of a 100-pound mass reduction in LTVs lighter than 5,014 pounds would be 4.9 divided by 1,782, or 0.28 percent, versus 0.31 percent in the baseline.

This simple example confirms that the estimates do indeed change as the distribution of curb weights changes. In this case, the change is intuitive: As the LTV fleet becomes lighter, mass reduction among LTVs below 5,014 pounds becomes less detrimental to society. However, the incremental effect is estimated to be quite small: Shifting from an even mix of LTVs above and below the threshold to an extreme 20%/80% split only changes the estimated net societal effect by 0.03 percent in absolute terms. Thus, the model results for lighter LTVs appear relatively insensitive to the LTV curb weight distribution. Indeed, in the limit, where all LTVs are below the crash-partner curb weight threshold (and thus there are no fatality impacts for

crashes involving heavier LTVs), the estimated net societal effect of a 100-pound mass reduction for LTVs below 5,014 pounds (i.e., *all* LTVs in this case) is 0.25 percent, a difference of 0.06 percent in absolute terms compared to the baseline. This result is driven by the dominating effects of crash types involving either: (1) no crash partner (e.g., first-event rollovers); (2) one crash partner from a group not associated with a given change in a curb weight distribution (e.g., heavy vehicles, bicyclists, passenger cars); or (3) multiple crash partners (an element of "all other crashes"). That is, even extreme changes in the distribution of curb weights for a given vehicle type will not change the role that vehicle mass plays in crashes for a focal vehicle when that vehicle does not collide with another vehicle from the distribution in question. In the above example involving lighter LTVs, 90 percent of fatalities involve incidents that do not include a single LTV crash partner, and 66 percent of fatalities involve incidents that do not include a single light-duty crash partner.

Continuing with this example scenario, the point estimate for LTVs heavier than 5,014 pounds becomes larger in magnitude (i.e., more societally beneficial mass reduction) to a similar degree as the reduction in magnitude for lighter LTVs when moving to an extreme 20%/80% split of crash partner LTVs above (versus below in the case above) the curb weight threshold:

Table VI-139 - Calculation of Example Alternative Safety Point Estimate (LTVs 5,014 Pounds or Heavier)

Crash Type	Share of Fatalities		Change in Fatality Risk per 100-Pound Mass Reduction for Crash Type (%)	Change in Fatalities per 100-Pound Mass Reduction for Crash Type (Baseline = 3,304)	
	NPRM	Example		NPRM	Example
First-Event Rollover	0.02	0.02	0.76	0.6	0.6
Hit Fixed Object	0.09	0.09	0.99	3.1	3.1
Hit Pedestrian/Bicycle/Motorcycle	0.19	0.19	0.02	0.1	0.1
Hit Heavy Vehicle	0.06	0.06	0.79	1.6	1.6
Hit Car/CUV/Minivan < 3,187 Lbs.	0.14	0.14	-2.56	-12.0	-12.0
Hit Car/CUV/Minivan 3,187+ Lbs.	0.13	0.13	-0.36	-1.5	-1.5
Hit Truck-Based LTV < 4,360 Lbs.	0.07	0.10	-1.81	-4.0	-6.1
Hit Truck-Based LTV 4,360+ Lbs.	0.06	0.03	0.81	1.6	0.7
All Other	0.24	0.24	-1.20	-9.5	-9.5
Total	1.00	1.00	NPRM: -0.61 Example: -0.69	-20.0	-22.9

In the NPRM and this analysis, the estimated net societal effect of a 100-pound mass reduction for lighter LTVs was a 20.0 fatality decrease, or a 0.61 percent decrease relative to a baseline of 3,304 fatalities. Changing the share of crash fatalities involving heavier LTVs to be consistent with a fleet with only 20 percent of LTVs above the curb weight threshold yields: (1) a larger reduction in fatalities in crashes involving lighter LTVs per 100-pound mass reduction

(from 4.0 fatalities to 6.1 fatalities); and (2) a decrease in incremental fatalities in crashes involving heavier LTVs (from 1.6 fatalities to 0.7 fatality); for a total net change of -22.9 fatalities compared to a baseline of -20.0 fatalities. Thus, we estimate that, in a future year where the fleet differs from the baseline by having 80 percent of LTVs below the crash-partner curb weight threshold, the net societal effect of a 100-pound mass reduction in LTVs 5,014 pounds or heavier would be -22.9 divided by 3,304, or -0.69 percent, versus -0.61 percent in the baseline. Consistent with the test results for lighter LTVs, the model results for heavier LTVs appear relatively insensitive to the LTV curb weight distribution. In the limit, where all LTVs (except for one remaining heavier LTV in consideration) are below the crash-partner curb weight threshold (and thus there are no effective fatality impacts for crashes involving heavier LTVs), the estimated net societal effect of a 100-pound mass reduction for the remaining LTV above 5,014 pounds is -0.76 percent, a difference of 0.15 percent in absolute terms compared to the baseline.

Expanding the analysis to account for changes in the relative sales shares of each vehicle type dampens the net effects further. As the fleet share of passenger cars decreases, the net effects of mass reduction among LTVs become less societally beneficial. That is, as there are fewer relatively vulnerable passenger cars in the fleet, there become fewer opportunities to reduce fatalities in collisions between LTVs and passenger cars through mass reduction. In some scenarios considered in the exploratory analysis, the effects of sales shifts from passenger cars to LTVs at least fully offset the estimated improvements in net fatalities associated with mass reduction summarized above as the LTV fleet becomes lighter.

Commented [A408]: REVISE: Pointing out that this is still missing the absolute change in fatality risk between pass cars, trucks, and CUVs.

Ultimately, the exploratory analysis using extreme example cases confirmed that the baseline safety point estimates are very reasonable for the feasible ranges of mixes of vehicle types and curb weights across the model years in the CAFE model analysis. The sensitivities of the point estimates are relatively low across relative shares of lighter versus heavier LTVs (especially relative to the uncertainty in the baseline estimates), and similarly low and offsetting across decreasing fleet shares for passenger cars. Because shifts in mass in the rulemaking analysis would have insignificant impacts on the safety estimated values and therefore rulemaking decision making, the agencies conclude no changes are warranted for this final rule analysis.

(3) Mass Safety Results

Table VI-140

Table VI-140 presents the estimated percent increase in U.S. societal fatality risk per 10 billion VMT for each 100-pound reduction in vehicle mass, while holding footprint constant, for each of the five vehicle classes:

Table VI-140 - Fatality Increase (Percent) per 100-Pound Mass Reduction While Holding Footprint Constant: MY 2004-2011, CY 2006-2012

	Central Estimate	95% Confidence Bounds
Cars < 3,201 pounds	1.20	-.35 to +2.75
Cars > 3,201 pounds	0.42	-.67 to +1.50
CUVs and minivans	-0.25	-1.55 to +1.04
Truck-based LTVs < 5,014 pounds	0.31	- .51 to +1.13
Truck-based LTVs > 5,014 pounds	-0.61	-1.46 to +.25

Techniques developed in the 2011 (preliminary) and 2012 (final) Kahane reports have been retained to test statistical significance and to estimate 95-percent confidence bounds (sampling error) for mass effects and to estimate the combined annual effect of removing 100 pounds of mass from every vehicle (or of removing different amounts of mass from the various classes of vehicles), while holding footprint constant.

None of the estimated effects have 95-percent confidence bounds that exclude zero, and thus are not statistically significant at the 95-percent confidence level. The NPRM reported that two estimated effects are statistically significant at the 85-percent level. Societal fatality risk is estimated to: (1) increase by 1.2 percent if mass is reduced by 100 pounds in the lighter cars; and (2) decrease by 0.61 percent if mass is reduced by 100 pounds in the heavier truck-based LTVs. The estimated increases in societal fatality risk for mass reduction in the heavier cars and the lighter truck-based LTVs, and the estimated decrease in societal fatality risk for mass reduction in CUVs and minivans are not significant, even at the 85-percent confidence level. Although 85-percent statistical significance is not a traditional metric of meaningful differences to zero, this result confirms that the estimated effects for vehicles with curb weights most dissimilar to the median vehicle are the most likely to be significantly different to zero.

The agencies judge the central value estimates are the best and most up-to-date estimates available; the estimates offer a stronger statistical representation of relationships among vehicle curb weight, footprint and fatality risk than an assumption of no correlation whatsoever. The agencies appropriately present the statistical uncertainty. For example, the central values for the highest vehicle weight group (LTVs 5,014 pounds or heavier) and the lowest vehicle weight group (passenger cars lighter than 3,201 pounds) (which, based on fundamental physics, are expected to have the greatest impact of mass reduction on safety) are economically significant[1492], and are in line with the prior analyses used in past NHTSA CAFE and EPA CO_2

[1492] The agencies use "economically significant results" to mean values that have an important, practical implication, but may be derived from estimates that do not meet traditional levels of statistical significance. For example, if the projected economic benefit of a project equaled $100 billion, the agencies would consider the impact economically significant, even if the estimates used to derive the impact were not statistically significant at the 95-percent confidence level. Conversely, if the projected economic benefit of a project equaled $1, the agencies would not consider the impact economically significant, even if the estimates used to derive the impact were statistically significant at the 99.99-percent confidence level. In the case above, we considered the results associated with the lightest and heaviest vehicle types to be economically significant because the associated safety costs were large and the estimates had magnitudes meaningfully different from zero and were statistical significant at the 85-percent confidence level.

rulemakings. As shown in Table VI-141Table VI-141, the estimated coefficients have trended to lower numerical values in successive studies, but remain positive for lighter cars and negative for heavier LTVs. The 85-percent confidence level was reported only to show the scope of uncertainty at the first rounded (to five percent) threshold where the coefficient estimates were significantly different to zero for the two vehicle groups at the extremes of the curb weight distribution. No preference was suggested for an 85-percent confidence bound. Rather, the agencies found value in reporting confidence intervals for all five coefficients at the threshold where the estimates for the two extremes of the curb weight distribution were significantly different to zero. The agencies determined it was better to include the estimates, despite the slightly lower confidence level, than knowingly omitting economically significant results.

The regression results are constructed to project the effect of changes in mass, independent of all other factors, including footprint. With each additional change from the current environment (e.g., the scale of mass change, presence and prevalence of safety features, demographic characteristics), the results may become less representative. That is, although safety features and demographic factors are accounted for separately, the estimated effects of mass are identified under the specific mix of vehicles and drivers in the data. We note that the analysis accounts for safety features that are optional but available across all MYs in the sample (most notably electronic stability control, which was not yet mandatory for all model years in the sample), and calibrates historical safety data to account for future fleets with full ESC penetration to reflect the mandate.

The agencies considered the near multicollinearity of mass and footprint to be a major issue in the 2010 Kahane report and voiced concern about inaccurately estimated regression coefficients. High correlations between mass and footprint and variance inflation factors (VIF) have persisted from MY 1991-1999 to MY 2004-2011; large footprint vehicles continued to be, on the average, heavier than small footprint vehicles to the same extent as in the previous decade.

Nevertheless, multicollinearity appears to have become less of a problem in the 2012 Kahane, 2016 Puckett and Kindelberger/Draft TAR, and current analyses. Ultimately, only three of the 27 core models of fatality risk by vehicle type in the current analysis indicate the potential presence of effects of multicollinearity, with estimated effects of mass and footprint reduction greater than two percent per 100-pound mass reduction and one-square-foot footprint reduction, respectively; these three models include passenger cars and CUVs in first-event rollovers, and CUVs in collisions with LTVs greater than 4,360 pounds. This result is consistent with the 2016 Puckett and Kindelberger report, which also found only three cases out of 27 models with estimated effects of mass and footprint reduction greater than two percent per 100-pound mass reduction and one-square-foot footprint reduction.

For comparison, Table VI-141Table VI-141 shows the fatality coefficients from the 2012 Kahane report (MY 2000-2007 vehicles in CY 2002-2008) and the 2016 Puckett and Kindelberger report and Draft TAR (MY 2003-2010 vehicles in CY 2005-2011).

Table VI-141 - Fatality Increase (%) per 100-Pound Mass Reduction While Holding Footprint Constant

Vehicle Class[1493]	2012 Report Point Estimate	2016 Report/Draft TAR Point Estimate	2012 Report 95% Confidence Bounds	2016 Report 95% Confidence Bounds
Lighter Passenger Cars	1.56	1.49	+.39 to +2.73	-.30 to +3.27
Heavier Passenger Cars	.51	.50	-.59 to 1.60	-.59 to +1.60
CUVs and minivans	-.37	-.99	-1.55 to +.81	-2.17 to +.19
Lighter Truck-based LTVs	.52	-.10	-.45 to +1.48	-1.08 to +.88
Heavier Truck-based LTVs	-.34	-.72	-.97 to +.30	-1.45 to +.02

The new results are directionally the same as in 2012; in the 2016 analysis, the estimate for lighter LTVs was of opposite sign (but small magnitude). Consistent with the 2012 Kahane and 2016 Puckett and Kindelberger reports, mass reductions in lighter cars are estimated to lead to increases in fatalities, and mass reductions in heavier LTVs are estimated to lead to decreases in fatalities.

The estimated mass effect for heavier truck-based LTVs is stronger in this analysis and in the 2016 Puckett and Kindelberger report than in the 2012 Kahane report; both estimates are statistically significant at the 85-percent confidence level, unlike the corresponding estimate in the 2012 Kahane report. The estimated mass effect for lighter truck-based LTVs is insignificant and positive in this analysis and the 2012 Kahane report, while the corresponding estimate in the 2016 Puckett and Kindelberger report was insignificant and negative.

Multiple commenters, including the South Coast Air Quality Management District and States and Cities, challenged the practical value of using estimates with statistical significance at the 85-percent level, arguing that below 95 (or 90) percent are insufficiently reliable.[1494] For example, CARB stated, "[d]ue to the lack of statistical significance, NHTSA should not be attributing any increase in fatalities due to mass reduction" and argues that the "effect of mass reduction on fatality risk should be set to zero since the estimates are not statistically different to zero."[1495]

The agencies believe the updated analysis that was presented in the NPRM represents the most up to date and best estimate of the impacts of mass reduction on crash fatalities; and, that it

[1493] Median curb weights in the 2012 Kahane report: 3,106 pounds for cars, 4,594 pounds for truck-based LTVs. Median curb weights in the 2016 Puckett and Kindelberger report: 3,197 pounds for cars, 4,947 pounds for truck-based LTVs.

[1494] *See* South Coast Air Quality Management District, Detailed Comments, Docket No. NHTSA-2018-0067-11813, at 6 (internal citation omitted); *and* States and Cities, Detailed Comments, Docket No. NHTSA-2018-0067-11735, at 95.

[1495] CARB, Detailed Comments, Docket No. NHTSA-2018-0067-11873, at 269.

is appropriate for the analysis to use the best and most likely estimates for safety, even if the estimates are not statistically significant at the 95-percent confidence level, rather than assuming the unlikely likely scenario that changes in vehicle mass have no impact on safety. Significance at the 85-percent confidence level is important evidence that the relevant point estimates are meaningfully different to zero (e.g., approximately five to six times more likely to be non-zero than zero). The agencies believe it would be misleading to ignore these data or to use values of zero for the rulemaking analysis, as doing so would not properly inform decision makers on the safety impacts of the regulatory alternatives and final standards. Similar to past analyses, the NPRM and this final rule analysis use the best available estimates. The agencies feel it is inappropriate to ignore likely impacts of the standards simply because the best available estimates have confidence levels below 95 percent; uniform estimates of zero are statistically weaker than the estimates identified in the analysis, and thus are not the best available. Because the point estimates are derived from the best-fitting estimates for each crash type (all of which are non-zero), the confidence bounds around an overall estimate of zero would necessarily be larger than the corresponding confidence bounds around the point estimates presented here.

Commented [A409]: REVISE: This is misleading, and not really responsive to the commenters. No one is suggesting that changes in vehicle mass have no impact on safety; rather, they are suggesting that there is an unacceptable degree of uncertainty in the calculated numbers – which is exactly what the given "confidence level" implies.

In addition, although the confidence bounds of the point estimates are given, NHTSA has never taken the next logical step, which is to calculate the confidence bounds on the resulting fatality numbers. This is particularly important, as point estimate bounds are on either side of zero, meaning the change in fatalities that is calculated using one specific point estimate are (relatively) large, while the total is then (relatively) small.

At a broader level, multiple commenters asserted that the role of safety-related estimates should be restricted because of what they claim is a weak historical relationship between fuel economy and vehicle safety. For example, the Green Energy Institute at Lewis & Clark Law School commented, "[o]ver the past 40 years, per-capita vehicle fatalities decreased by 50%, while average fuel economy doubled."[1496] However, this statistic is misleading because it does not account for vehicle safety factors and changes in driving behavior external to fuel economy (e.g., FMVSS and other safe design advances, reductions in drunk driving, increases in seat belt use). That is, fatality rates have decreased due to a range of factors that are unrelated to fuel economy efforts. The methodology in the 2012 Kahane report, the 2016 Puckett and Kindelberger, the Draft TAR, the 2018 NPRM analysis and today's final rule analysis addresses these other changes in order to isolate the impacts of mass reduction alone. The role of the safety analysis outlined in this document is to isolate incremental effects on safety outcomes that are related to changes in fuel economy.

Multiple commenters disagreed with the results in

[1496] Green Energy Institute at Lewis & Clark Law School, Docket No. NHTSA-2018-0067-12213, at 3.

Table VI-140

Table VI-140, maintaining that mass reduction need not reduce societal safety. EDF cited a Michigan Manufacturing Technology Center (MMTC) review as supporting that widespread lightweighting would decrease crash severity through reduced kinetic energy in multiple-vehicle crashes. Similarly, the Aluminum Association commented, "[v]ehicle size, not weight, has been shown to be the leading safety determinant."[1497] Other commenters cited Anderson and Auffhammer (2014), which finds that the safety effects of mass reduction in one vehicle are offset by the safety effects in the crash partner vehicle.[1498] The South Coast Air Quality Management District asserted that NHTSA and EPA appear to argue "that fuel-efficient vehicles are lighter than other vehicles, and therefore, less safe." The North Carolina Department of Environmental Quality asserted that a takeaway from the preferred alternative is that larger vehicles are safer than smaller vehicles. The agencies' conclusion is that, at the societal level, it is the distribution of changes in vehicle mass that matter (i.e., mitigating mass reduction in the lightest vehicles is societally beneficial, while mitigating mass reduction in the heaviest vehicles is societally harmful).

The 2012 Kahane report, the 2016 Puckett and Kindelberger, the Draft TAR, the 2018 NPRM analysis and today's final rule analysis all have shown that both mass and vehicle size impact societal safety. Across recent rulemakings, the analyses have confirmed a protective effect of vehicle size (i.e., societal fatality risk decreases as footprint increases). As mentioned previously, the agencies believe vehicle footprint-based standards help to discourage vehicle manufacturers from downsizing their vehicles, and therefore assume changes in CAFE and CO_2 standards will not impact vehicle size and size-related safety impacts. On the other hand, mass reduction is a cost-effective technology for increasing fuel economy and reducing CO_2 emissions. Therefore, the agencies do include the assessment of safety impacts related to mass reduction. As discussed throughout this mass-safety subsection and in FRIA Chapter 11, we present comprehensive consideration of the various studies and workshops on the impact of vehicle mass on safety, and conclude there is in fact a relationship. The fleet simulation study, discussed in the next subsection, further supports the existence of this relationship and that this relationship will continue to exist in future vehicle designs.

The principal difference between heavier vehicles, especially truck-based LTVs, and lighter vehicles, especially passenger cars, is that mass reduction has a different effect in collisions with another car, LTV, or other object such as a lamp post. When two vehicles of unequal mass collide, the change in velocity (delta-V) is greater in the lighter vehicle. Through conservation of momentum, the degree to which the delta-V in the lighter vehicle is greater than in the heavier vehicle is proportional to the ratio of mass in the heavier vehicle to mass in the lighter vehicle:

$$\Delta v_1 = \frac{m_2}{m_1} \Delta v_2$$

Where:

[1497] The Aluminum Association, Detailed Comments, Docket No. NHTSA-2018-0067-12213, at 3.
[1498] Anderson, M.L. and M. Auffhammer (2014). "Pounds that Kill," *Review of Economic Studies*, Vol. 81, No. 2, pp. 535-71.

Δv_1 is the delta-V for a focal vehicle,

Δv_2 is the delta-V for a partner vehicle, and

$\frac{m_2}{m_1}$ is the mass of the partner vehicle divided by the mass of the focal vehicle.

Because fatality risk is a positive function of delta-V, the fatality risk in the lighter vehicle in two-vehicle collisions is also higher. Vehicle design can reduce the magnitude of delta-V to some degree (e.g., changing the stiffness of a vehicle's structure could dampen delta-V for both crash partners). These considerations drive the overall result; mass reduction is associated with an increase in fatality risk in lighter cars, a decrease in fatality risk in heavier LTVs, CUVs, and minivans, and has smaller effects in the intermediate groups. Mass reduction may also be harmful in a crash with a movable object such as a small tree, which may break if hit by a high mass vehicle resulting in a lower delta-V than may occur if hit by a lower mass vehicle which does not break the tree and therefore has a higher delta-V. However, in some types of crashes not involving collisions between cars and LTVs, especially first-event rollovers and impacts with fixed objects, mass reduction may not be harmful and may even be beneficial.

Ultimately, delta-V is a direct function of relative vehicle mass for given vehicle structures. Removing some mass from the heavier vehicle involved in an accident with a lighter vehicle reduces the delta-V in the lighter vehicle, where fatality risk is higher, resulting in a large benefit to the passengers of the lighter vehicle. This is partially offset by a small increase in the delta-V in the heavy vehicle; however, the fatality risk is lower in the heavier vehicle and remains relatively low despite the increase in delta-V. In sum, the change in mass and delta-V from mass reduction in heavier vehicles results in a net societal benefit.

Multiple commenters claimed that the agencies' analysis does not allow for the likely outcome that mass reduction would be concentrated among relatively heavy vehicles.[1499] For example, Global Automakers commented that the agencies should not include weight reduction in their safety analysis because "very few vehicles [have] implemented lightweight material substitution strategies."[1500]

Neither CAFE standards nor this analysis mandate mass reduction, or mandate mass reduction occur in any specific manner. As discussed in the mass reduction technology section of the FRIA (see Chapter [6.3] of the regulatory impact analyses for detail), mass reduction is a highly cost effective technology for improving fuel economy and CO_2 emissions. The steel, aluminum, plastics, composite, and other material industries are developing new materials and manufacturing equipment and facilities to produce those materials. In addition, suppliers and manufacturers are optimizing designs to maintain or improve functional performance with lower mass. Manufacturers have stated that they will continue to reduce vehicle mass to meet more stringent standards, and therefore, this expectation is incorporated into the modeling analysis supporting the standards to: (1) determine capabilities of manufacturers; and (2) to predict costs

[1499] *See* also, for example: South Coast Air Quality Management District, Detailed Comments, Docket No. NHTSA-2018-0067-11813, at 6.
[1500] Association of Global Automakers, Attachment A, Docket No. NHTSA-2018-0067-12032, at A-32.

and fuel consumption effects of CAFE standards. The CAFE and CO_2 rulemakings in 2012, the Draft TAR and EPA Preliminary Determination, imposed an artificial constraint on vehicle mass reduction to achieve a desired safety-neutral outcome. For the current rulemaking, this artificial constraint is eliminated so the analysis reflects manufacturers applying the most cost effective technologies to achieve compliance with the regulatory alternatives and the final standards; this approach allows mass reduction to be applied across the fleet. This is consistent with industry trends.[1501] To the extent that mass reduction is only cost-effective for the heaviest vehicles, the CAFE model would create the outcome predicted by commenters. In reality, however, mass reduction is a cost-effective means of improving fuel economy and does take place across vehicles of all sizes and weights. Accordingly, the model reflects that manufacturers may reduce vehicle mass—regardless of vehicle class—when doing so is cost effective.

The National Tribal Air Association claimed the 2015 NAS study found "evidence suggest[ing] that the [2012] standards will lead the nation's light-duty vehicle fleet to become lighter but not less safe."[1502] The agencies note the NAS quote is one phrase from the press release that accompanied the NHTSA sponsored 2015 NAS study,[1503] and the agencies do not believe the phrase in isolation reflects the findings of the NAS Committee, which are discussed in over 3 pages of the report.[1504] The 2015 NAS report supported the analytical methodology used for the 2012 NHTSA CAFE and EPA CO_2 rulemaking and found it reasonable. As discussed in the subsections further above, a nearly identical methodology was used for the NPRM analysis and for this final rule.

The agencies received several comments about the relationship between mass and crash avoidance. The NRDC commented that the analysis should account for the expected result that mass reduction makes it easier to avoid crashes.[1505] Conversely, IPI quoted a finding by LNL that "found that mass reductions may increase the number of accidents but that each crash results in fewer fatalities."[1506]

The phenomenon touched upon by IPI and NRDC has been identified in past rulemakings as well, and highlights that the relationship between mass reduction and societal fatality risk include two partially-offsetting components (i.e., increased exposure to crashes is offset partially by decreased risk in some vehicles conditional on a crash occurring). The agencies note that this

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[1501] The baseline MY 2016 (for the NPRM) and MY 2017 (for this final rule analysis) vehicle fleet data show manufacturers have in fact implemented mass reduction technology across vehicle types and sizes– including smaller and lighter vehicles.

[1502] National Tribal Air Association, Detailed Comments, Docket No. NHTSA-2018-0067-11948, at 2.

[1503] NAS (2015). Press Release. "Analysis Used by Federal Agencies to Set Fuel Economy and Greenhouse Gas Standards for U.S. Cars Was Generally of High Quality; Some Technologies and Issues Should Be Re-examined." June 18, 2015. (http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=21744).

[1504] Key excerpts from the report include: "[o]ccupants of smaller vehicles are at a greater risk of fatality in crashes, particularly in a crash with a vehicle of greater mass"; and "[t]he 2012 studies (by NHTSA, Lawrence Berkeley National Laboratories, and Dynamic Research, Inc.) indicate that mass reduction while holding footprint constant is associated with a small increase in risk for lighter-than-average cars only; the estimated effect on other vehicle types is not statistically significant." National Research Council (2015). *Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles*, available at https://doi.org/10.17226/21744, pp. 224-28.

[1505] NRDC, Detailed Comments, Docket No. NHTSA-2018-0067-11973.

[1506] IPI, Detailed Comments, Docket No. NHTSA-2018-0067-12213, at 129.

relationship, while not reported separately, is in fact embedded within the analysis detailed in this document, as the extent to which some vehicles are more maneuverable and faster-braking, the crash data reflect those characteristics through lower observed fatality rates. However, when considering the purposes of estimating effects of mass reduction on fatalities, it is immaterial what share of the effect is comprised of crash avoidance factors and crashworthiness factors, the ultimate effect is present within the data evaluated in the analysis. The mass-safety impacts estimated by the statistical analysis of crash data are based on the safety technologies and mass levels present among the vehicle fleets for the calendar and model years in the data. As discussed in Section [Text Forthcoming], the analysis separately accounts for the effects of future safety technologies.

(4) Sensitivity Analysis

Table VI-142Table VI-142 shows the principal findings and includes sampling-error confidence bounds for the five parameters used in the CAFE model. The confidence bounds represent the statistical uncertainty that is a consequence of having less than a census of data. NHTSA's 2011, 2012, and 2016 reports acknowledged another source of uncertainty: The central (baseline) statistical model can be varied by choosing different control variables or redefining the vehicle classes or crash types, which for example, could produce different point estimates.

Beginning with the 2012 Kahane report, NHTSA has provided results of 11 plausible alternative models that serve as sensitivity tests of the baseline model. Each alternative model was tested or proposed by: Farmer (IIHS) or Green (UMTRI) in their peer reviews; Van Auken (DRI) in his public comments; or Wenzel in his parallel research for DOE. The 2012 Kahane and 2016 Puckett and Kindelberger reports provide further discussion of the models and the rationales behind them.

Alternative models use NHTSA's databases and regression-analysis approach but differ from the central model in one or more explanatory variables, assumptions, or data restrictions. We applied the 11 techniques to the latest databases to generate alternative CAFE model coefficients. The range of estimates produced by the sensitivity tests offers insight to the uncertainty inherent in the formulation of the models, subject to the caveat that these 11 tests are, of course, not an exhaustive list of conceivable alternatives.

The central and alternative results follow, ordered from the lowest to the highest estimated increase in societal risk per 100-pound reduction for cars weighing less than 3,201 pounds:

Table VI-142 - Fatality Increase (%) Per 100-Pound Mass Reduction While Holding Footprint* Constant

	Cars	Cars	CUVs &	LTVs†	LTVs†
	< 3,201	≥ 3,201	Minivans	< 5,014	≥ 5,014
Central Estimate	1.20	0.42	-0.25	0.31	-0.61

95% confidence bounds	Lower:	-0.35	-0.67	-1.55	-0.51	-1.46
(sampling error)	Upper:	2.75	1.50	1.04	1.13	0.25
11 Alternative Models						
1. Without CY control variables		0.26	-0.07	-0.58	0.35	-0.16
2. By track width & wheelbase		0.66	0.54	-0.48	-0.44	-0.90
3. Track width/wheelbase w. stopped veh data		0.73	-0.02	-0.18	-0.77	-1.91
4. Without non-significant control variables		0.98	0.26	0.14	0.36	-0.50
5. CUVs/minivans weighted by 2010 sales		1.20	0.42	-0.07	0.31	-0.61
6. With stopped-vehicle State data		1.32	-0.17	-0.08	0.21	-1.55
7. Including muscle/police/AWD cars/big vans		1.56	1.01	-0.25	0.87	0.43
8. Limited to drivers with BAC=0		1.83	1.47	-0.05	0.40	-0.80
9. Control for vehicle manufacturer		2.09	1.51	-0.01	1.12	0.30
10. Limited to good drivers‡		2.15	1.80	-0.33	0.4	-0.45
11. Control for vehicle manufacturer/nameplate		2.26	2.70	-0.48	1.12	0.50

*While holding track width and wheelbase constant (rather than footprint) in alternative model nos. 2 and 3.

†Excluding CUVs and minivans.

‡BAC=0, no drugs, valid license, at most one crash and one violation during the past three years.

For example, in cars weighing less than 3,201 pounds, the baseline estimate associates 100- pound mass reduction, while holding footprint constant, with a 1.56% increase in societal fatality risk. The corresponding estimates for the 11 sensitivity tests range from a 0.26 to a 2.15% increase.

The sensitivity tests illustrate both the fragility and the robustness of central estimates. On the one hand, the variation among the coefficients is quite large relative to the central estimate: in the preceding example of cars < 3,201 pounds, the estimated coefficients range from almost zero to almost double the central estimate. This result underscores the key relationship that the societal effect of mass reduction is small. In other words, varying how to model some of these other vehicle, driver, and crash factors, which is exactly what sensitivity tests do, can appreciably change the estimate of the societal effect of mass reduction.

On the other hand, variations are not particularly large in absolute terms. The ranges of alternative estimates are generally in line with the sampling-error confidence bounds for the central estimates. Generally, in alternative models as in the central model, mass reduction tends to be relatively more harmful in the lighter vehicles and more beneficial in the heavier vehicles, just as they are in the central analysis. In all models, the point estimate of the coefficient is positive for the lightest vehicle class, cars < 3,201 pounds. In 10 out of 11 models, the point estimate is negative for CUVs and minivans, and in nine out of 11 models the point estimate is negative for LTVs ≥ 5,014 pounds. We believe the central case uses the most rigorous methodology, as discussed further above, and provides the best estimates of the impacts of mass reduction on safety.

Tom Wenzel commented confirming a preference for the alternative model with footprint separated into track width and wheelbase, and with the induced exposure data limited to stopped vehicle cases.[1507] Wenzel asserts that splitting footprint into its components reduces multicollinearity with curb weight, and that limiting induced exposure cases to stopped vehicles mitigates bias against driver-vehicle pairs that are less likely to be involved in crashes. Based on this feedback and the intuitiveness of the approach, we further considered the alternative model with footprint split into track width and wheelbase. Consistent with previous analyses and assessments, there are problems with splitting footprint into its components within the mass-size-safety models because of strong correlations among curb weight, track width and wheelbase. For all vehicle classes in the analysis, curb weight is correlated either nearly as high or higher with track width as with footprint. Track width and wheelbase are also highly correlated with one another (ranging from around 0.64 to 0.80, with the exceptions of smaller correlations for large pickups and minivans). Viewed from another angle, wheelbase is almost perfectly correlated with footprint (with correlations ranging from around 0.95 to 0.97).

Considered in concert, the track width and wheelbase model not only essentially incorporates the full correlation issues from the baseline model (curb weight highly correlated with another independent variable), but also adds a further correlation issue (the variable that is highly correlated with curb weight is also highly correlated with a separate independent variable). We examined supplementary means of confirming the relative methodological merit of the footprint-based model and the track-width-wheelbase-based alternative. The supplementary analysis centered on the *condition index*, which quantifies the invertibility of the matrix of independent variables in a given model through its measure, the *condition number*.[1508] A model with a low condition number has relatively low correlations among its independent variables, and thus its invertibility and the corresponding model outputs are robust to variations in model input values. A model with a high condition number has relatively high correlations among its independent variables, and thus its invertibility and model outputs are *not* robust to variations in model input values. That is, a model with a high condition number is likely to be subject to the problems associated with multicollinearity. Although there is no strict threshold condition number value to indicate multicollinearity, higher values indicate greater likelihood that the independent variables are correlated to a problematic degree.

The condition index offers an alternative means of capturing the same forces as the variance inflation factor (VIF), which the agencies have used historically (including in this rulemaking) as a diagnostic of multicollinearity. However, the condition index offers some advantages relative to the VIF. Notably, the condition index applies regardless of the econometric form of the model (i.e., the decomposition of the independent variables is the same regardless of how the variables are applied in the model). This is distinct from the VIF, which is limited to a linear diagnostic of the data that may not map well to non-linear econometric models, including the logistic regression models that form the core of the curb weight-fatality

[1507][1507] Wenzel, T., Lawrence Berkeley National Laboratories, Docket No. EPA-HQ-OAR-2018-0283-4118.
[1508] *See* Belsley, D. A., Kuh, E., and Welsch, R. E. (1980). "The Condition Number". *Regression Diagnostics: Identifying Influential Data and Sources of Collinearity*. New York: John Wiley & Sons; Freund, R.J. and Littell, R.C. (2000). *SAS System for Regression, Third Edition*. Cary, NC: SAS Institute, Inc.; and Hallahan, C. (1995). "Understanding the Multicollinearity Diagnostics in SAS/Insight and Proc Reg." SAS Conference Proceedings, Washington, DC, October 8-10, 1995.

risk analysis. The condition index estimates the incremental effects of individual variables, which is helpful in an analysis of which independent variables are the most problematic. Conversely, the diagnostic values from the VIF are not necessarily sensitive to incremental correlated variables, as the VIF value ($1/(1-R^2)$ does not necessarily change much once correlations are relatively high (i.e., when R^2 is already high, the inclusion of one or more highly correlated variables may not change R^2, and in turn, the VIF, by much.

An incremental comparison of VIF estimates for the data confirmed the potential weakness of the VIF in this case. For the CUV-minivan model data, the VIF *decreases* from 9.4 to 6.7 when: (1) substituting either track width or footprint for footprint that has an identical correlation with curb weight as footprint; and (2) adding the other component of footprint. This result is counterintuitive (i.e., the simpler model should necessarily have fewer issues of multicollinearity), and may be an artifact of differences in model fit (e.g., a higher R^2 in the simpler model could indicate better model fit rather than anything problematic in terms of correlation structure). This resnlt led the agencies to question how well the VIF identifies relative impacts of multicollinearity across related models, especially in non-linear applications.

The calculated condition numbers for the curb weight-footprint models and their corresponding curb weight-wheelbase-track width alternatives were consistent with expectations regarding multicollinearity, however. The condition numbers for the curb weight-wheelbase-track width models are approximately two to three times higher than the condition numbers for the curb weight-footprint models. This indicates that the level of imprecision in model estimates using track width and wheelbase would be expected to be between approximately two to three times higher than in the baseline models using footprint. Unlike the VIF, the condition index supports a hypothesis that multicollinearity would not be mitigated in an alternative with disaggregated variables that are highly correlated with both the variable of interest and the variable they are replacing. Considering these results, the agencies that using footprint to represent vehicle size in the safety models provides a more reliable estimate of safety impacts than splitting footprint into track width and wheelbase.

The agencies also considered the use of stopped-vehicle data as an alternative. The primary problem with this approach is that we do not observe as large of a share of cases on roads with higher travel speeds (e.g., interstate highways) when including only stopped vehicles; this relationship influences the extent to which the induced exposure data reflect the distributions of driver attributes and contextual effects across national VMT. Based on this assessment, the agencies believe the methodology used for the analysis in the proposal provides a more reliable and representative estimate of safety impacts, and thus is not changing the methodology for today's final rule.

In a related comment, Wenzel proposes that future analyses should directly account for differences in curb weight between vehicles in two-vehicle crashes. The agencies believe that would require the development of a model that directly accounts for the relative weights of vehicles in two-vehicle crashes, and that such a model would require peer review. Key alternatives to test would vary in terms of the functional form of the mass disparity between two crash partners (e.g., a relative mass ratio consistent with the delta-V calculation presented above,

linear mass difference, non-linear mass difference). We will consider initiating work to explore such a model in the future.

DRI requested the agencies clarify whether the analysis accounts for all road users (i.e., including pedestrians, bicyclists, motorcyclists, and other crash partners), while the Pennsylvania Department of Environmental Protection commented, "[i]t is inadequate for the agencies' analysis for this Proposed Rule to only focus on frontal crashes while omitting near-frontal collisions, side-impact collisions, rear-end collisions, rollover accidents, impacts with stationary objects and accidents involving pedestrians."[1509] The agencies confirm that the analysis presented in this section continues to apply the methodology developed by Kahane, which incorporates all road users, without double-counting, to identify societal fatality rate impacts. Because every fatal crash (across crash types) is included in the analysis, not just frontal crashes, the agencies find this comment lacks a basis. We believe the commenter's confusion may stem from the use of front-to-back crashes to generate estimates of the proportions of all driving for each vehicle model associated with particular characteristics of drivers (e.g., age, gender) and crashes (e.g., urban/rural, day/night). These crashes represent the best available trade-off among sample size, representativeness of overall vehicle and driver exposure, and mitigating bias in a sample that is intended to be effectively random (i.e., the probability of being struck from behind by an at-fault driver is assumed to be a function of characteristics of other drivers and travel demand, but not of the struck driver or the struck vehicle).

(5) Fleet Simulation Study

Commenters to recent CAFE rulemakings, including some vehicle manufacturers, have suggested designs and materials of more recent model year vehicles may have weakened the historical statistical relationships between mass, size, and safety. NHTSA and EPA agreed that the statistical analysis would be improved by using an updated crash and exposure database reflecting more recent safety technologies, vehicle designs and materials, and reflecting changes in the vehicle fleet. As mentioned above, a new crash and exposure database was created with the intention of capturing modern vehicle engineering and has been employed for assessing safety effects for CAFE rules since 2012.

The agencies have traditionally relied solely on real-world crash data as the basis for projecting the future safety implications for regulatory changes. The agencies are required to consider relevant data in setting standards.[1510] Every fleet regulated by the agencies' standards differs from the fleet used to establish said standard, and as such, the light-duty vehicle fleet in the MY 2021-2026 timeframe will be different from the MY 2004-2011 fleet analyzed above. This is not a new or unique phenomenon, but instead is an inherent challenge in regulating an industry reliant on continual innovation. This is the agencies' sixth evaluation of effects of mass reduction and/or downsizing,[1511] comprising databases ranging from MYs 1985 to 2011. Despite

[1509] Pennsylvania Department of Environmental Protection, Detailed Comments, Docket No. NHTSA-2018-0067-11956, at 9.

[1510] *See* Center for Biological Diversity v. NHTSA, 538 F.3d 1172, 1203 (9th Cir. 2008).

[1511] As outlined throughout this section, NHTSA's six related studies include the new analysis supporting this rulemaking, and: Kahane, C. J. *Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99*

continual claims that modern lightweight engineering will render current data obsolete, results of the six studies, while not identical, have been generally consistent in showing a small, negative impact related to mass reduction. The agencies strongly believe that real-world crash data remains the best, relevant data to measure the effect of mass reduction on safety.

However, because lightweight vehicle designs introduce fundamental changes to the structure of the vehicle, there remains a persistent question of whether historical safety trends will apply. To address this concern and to verify that real-world crash data remain an appropriate source of data for projecting mass-safety relationships in the future fleet, in 2014, NHTSA sponsored research to develop an approach to utilize experimental lightweight vehicle designs to evaluate safety in a broader range of real-world representative crashes.[1512] NHTSA contracted with George Washington University to perform a fleet simulation model to study the impact and relationship of light-weighted vehicle design with injuries and fatalities.[1513] The study involved simulating crashes on eight test vehicles, five of which were equipped with lightweight materials and advanced designs not yet incorporated into the U.S. fleet.[1514] The study assessed a range of frontal crashes, including crashes with fixed objects and other vehicles, across wide range of vehicle speeds, and with mid-size male and mid-size female dummies.[1515] In all, more than 440 vehicle crashes with 1,520 dummy passengers were simulated for a range of crash speeds and crash configurations. Results from the fleet simulation study showed the trend of increased societal injury risk for light-weighted vehicle designs occurs for both single vehicle and two-vehicle crashes. Results are listed in

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Passenger Cars and Light Trucks, National Highway Traffic Safety Administration (Oct. 2003), available at https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/809662; Kahane, C. J. *Relationships Between Fatality Risk, Mass, and Footprint in Model Year 1991-1999 and Other Passenger Cars and LTVs* (Mar. 24, 2010), in *Final Regulatory Impact Analysis; Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*, National Highway Traffic Safety Administration (Mar. 2010) at 464-542; Kahane, C. J. *Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs – Preliminary Report*, National Highway Traffic Safety Administration (Nov. 2011), available at Docket ID NHTSA-2010-0152-0023); Kahane, C. J. *Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs: Final Report, NHTSA Technical Report.* Washington, D.C.: NHTSA, Report No. DOT-HS-811-665; and Puckett, S. M., & Kindelberger, J. C. *Relationships between Fatality Risk, Mass, and Footprint in Model Year 2003-2010 Passenger Cars and LTVs – Preliminary Report*, National Highway Traffic Safety Administration (June 2016), available at https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/2016-prelim-relationship-fatalityrisk-mass-footprint-2003-10.pdf.

[1512] Details of NHTSA's approach are described in FRIA Chapter [XX]. *See also* 83 FR at 43133 (Aug 24, 2018).

[1513] Samaha, R. R., Prasad, P., Marzougui, D., Cui, C., Digges, K., Summers, S., Patel S., Zhao, L., & Barsan-Anelli, A. (2014, August). Methodology for evaluating fleet protection of new vehicle designs - Application to lightweight vehicle designs. Report No. DOT HS 812 051A, Washington, DC - National Highway Traffic Safety Administration.

[1514] The George Washington University fleet simulation study is described in greater detail in Chapter 11 of the FRIA.

[1515] Regulatory and consumer information crash safety tests are performed at high speeds, and the dummy occupant is generally a mid-size male. In the real world, crashes occur at various impact velocities and configurations; with various impact partners (e.g., rigid obstacles, lighter or heavier vehicles); and involve occupants of various sizes and ages.

Table VI-143

Table VI-143.[1516]

[1516] This fleet simulation study does not provide information that can be used to modify coefficients derived for the NPRM regression analysis because of the restricted types of crashes and vehicle designs. Additionally, the fleet simulation study assumed restraint equipment to be as in the baseline model, in which restraints/airbags are not redesigned to be optimal with light-weighting.

Table VI-143 - Overall Societal Risk Calculation Results for Model Runs, with Base Vehicle Restraint and Airbag Settings Being the same for All Vehicles, in Frontal Crash Only

Target Vehicle	Passenger Car Baseline	Passenger Car LW	CUV Baseline	CUV Low Option	CUV High Option
Weight (lbs)	3681	2964	3980	3313	2537
reduction		716		668	1444
% mass reduction		19%		17%	36%
Societal Risk I	1.56%	1.73%	1.36%	1.46%	1.57%
Delta Increase		0.17%		0.10%	0.21%
Societal Risk II	1.43%	1.57%	1.14%	1.20%	1.30%
Delta Increase		0.14%		0.06%	0.16%
Societal Risk IIP	1.44%	1.59%			
Delta Increase		0.15%			

Societal Risk I - Target + Partner Combined AIS3+ risk of Head, Neck, Chest & Femur
Societal Risk II - Target + Partner Combined AIS3+ risk of Head, Neck, and Chest
Societal Risk IIP - Target + Partner Combined AIS3+ risk of Head, Neck, and Chest with A-Pillar Intrusion Penalty

The change in the safety risk from the fleet simulation study was directionally consistent with results for passenger cars from the 2012 Kahane report,[1517] the 2016 Puckett and Kindelberger report, and the analysis used for the proposal and today's final rule. As noted, fleet simulations were performed in frontal crash mode and did not consider other crash modes such as rollover crashes.[1518] The fleet simulation analysis confirmed that real-world crash data were still a reliable source for analyzing mass safety impacts.

Despite the results of the fleet simulation analysis, which was republished in the proposal, the agencies received additional comments questioning the assumption that relationships among vehicle mass, size, and fatality risk will continue in the future. For example, the Alliance for Vehicle Efficiency asserted that using lighter frame materials has no impact on safety, noting that any mass reduction strategies are applied to components that are unrelated to crash safety and crash ratings have not declined for vehicles over the past five years.[1519] CARB commented that the agencies did not account for new vehicle improvements and claimed the data used for the analysis was "not a good indicator of the safety performance of future purpose-designed lightweighted vehicles."[1520] Consumers Union offered a similar appraisal, indicating that the MYs in the sample are "unlikely to capture the current and future mass/fatality relationship of modern vehicles."[1521] While the Aluminum Association commented vehicle size,

1517 The 2012 Kahane study considered only fatalities, whereas, the fleet simulation study considered severe (AIS 3+) injuries and fatalities (DOT HS 811 665).
1518 The risk assessment for CUV in the regression model combined CUVs and minivans in all crash modes and included belted and unbelted occupants.
1519 Alliance for Vehicle Efficiency, Detailed Comments, Docket No. NHTSA-2018-0067-11696, at 11.
1520 CARB, Detailed Comments, Docket No. NHTSA-2018-0067-11873, at 270.
1521 Consumers Union, Detailed Comments, Docket No. NHTSA-2018-0067-12068, at 18.

not mass, is the only physical feature that impacts safety.[1522] The American Chemistry Council, Hyundai, and Tesla commented that it is feasible to utilize design improvements and technologies to offset the incremental risk for vehicle occupants associated with mass reduction.[1523] EDF said the mass-safety analysis didn't agree with conclusions from a study by the Michigan Manufacturing Technology Center.[1524] Other comments from States and Cities, American Honda, ICCT, the Aluminum Association, and NRDC shared these sentiments.[1525]

These comments and the MMTC study ignored the results of the fleet simulation study and seem premised on the notion that a vehicles' performance on NHTSA FMVSS, NHTSA voluntary NCAP, and IIHS voluntary safety tests is the only measure for assessing societal safety impacts for mass reduction. The regulatory and consumer information tests are representative of real-world, single-vehicle crash configurations. However, the tests are performed at constant speeds, and the dummy occupant is generally a mid-size male. In the real world, crashes occur at various impact velocities and configurations; with various impact partners (e.g., rigid obstacles, lighter or heavier vehicles); and involve occupants of various sizes and ages. The fleet simulation study, summarized above and in more detail in FRIA Chapter 11, assessed additional types of frontal crashes, including crashes with fixed objects and other vehicles at a wide range of vehicle speeds, and with mid-size male and mid-size female dummies. The fleet simulation study was more comprehensive and focused on the need to assess overall societal safety impacts. The fleet simulation study found that vehicle mass does impact safety with future lightweight vehicle designs that perform well on regulatory and consumer information tests.

The agencies received one comment regarding the fleet simulation analysis. CARB commented that the analysis tested too few vehicles and crash types, should have optimized restraints in the lightweighted models to simulate future safety improvements instead of using modern restraints, and lacked credibility because the results of the fleet simulation analysis did not reproduce the same results of other studies.[1526] CARB's comments demonstrate a general misunderstanding of the fleet simulation analysis; the analysis was not intended to serve as a prediction of how the future vehicle fleet will perform, but rather was an exploration of whether expected lightweighting techniques would alter the dynamic between mass reduction and safety. The analysis was not an attempt to model every potential vehicle construction or crash scenario. Attempting to simulate every future crash would be impractical and ineffective. The combination of vehicles and crash simulations were purposely selected to provide the strongest insight into the effective of lightweighting techniques. For passenger cars and light trucks, frontal crashes account for 58 percent of fatal crashes;[1527] it is appropriate to focus research on

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[1522] Aluminum Association, Detailed Comments, Docket No. NHTSA-2018-0067-11952, at 3.
[1523] [INSERT CITATIONS]
[1524] Michigan Manufacturing Technology Center study "Vehicle Lightweighting: A Review of the Safety of *Reduced Weight Passenger Cars and Light Duty Trucks*," October 2018, available at https://advocacy.consumerreports.org/wp-content/uploads/2018/10/CU-MMTC-Safety-Study-10-24-2018.pdf.
[1525] States and Cities, Detailed Comments, Docket No. NHTSA-2018-0067-11735 AT XX; American Honda, Detailed Comments, Docket No. NHTSA-2018-0067-11818, at 15. INSERT OTHER CITATIONS.
[1526] CARB, Detailed Comments, Docket No. NHTSA-2018-0067-11873, at 272-73.
[1527] Samaha, R. R., Prasad, P., Marzougui, D., Cui, C., Digges, K., Summers, S., Patel S., Zhao, L., & Barsan-Anelli, A (2014, August). Methodology for evaluating fleet protection of new vehicle designs - Application to lightweight vehicle designs. Report No. DOT HS 812 051A, Washington, DC - National Highway Traffic Safety Administration.

understanding the effects of mass reduction where the largest issue exists. For the study, the use of generic restraint systems as the foundations for the models was intentional so that the models would be more representative of a vehicle class rather than a specific vehicle. The models of the restraint systems represented designs currently in production at time of the study in terms of pretensioners, load limiters and air bag inflators. It is worth noting that in general, driver air bags are similar in most vehicles. And finally, the analysis was not an attempt to reproduce the 2012 Kahane report or any other study. The fact that the fleet simulation analysis showed mass-reduction to be detrimental in more types of vehicles than in the FARS data only further highlights the need to consider how today's standards may impact mass-safety. While in the future there may be resources and opportunity to expand the fleet simulation approach to other crash scenarios and, if they become available, to include additional vehicle mass reduction concepts, the lack of potential future data does not justify ignoring the data that currently exist.

From a higher perspective, the comments, and in particular CARB's comment, identify the problem with abandoning real-world crash data: there is no alternate methodology or data that can account for the full diversity of crash scenarios that occur in the real world. Real-world crash data is the only data type that can achieve that. Therefore, the agencies have determined that, while simulations can prove helpful to understanding potential effects of key crash scenarios and as a check on the agencies' preferred analysis, real-world data still is still the best, most relevant data available for assessing safety.

(6) Summary of Mass Safety Impacts

Table VI-144Table VI-144 through Table VI-149Table VI-149Table VI-146Table VI-146 show results of NHTSA's vehicle mass-size-safety analysis over the cumulative lifetime of MY 1977-2029 vehicles, for both the CAFE and CO_2 programs, based on the MY 2017 baseline fleet, accounting for the projected safety baselines.

Results are driven extensively by the degree to which mass is reduced in relatively light passenger cars and in relatively heavy vehicles because their coefficients in the logistic regression analysis have the most significant values. We assume any impact on fatalities will occur over the lifetime of the vehicle, and the chance of a fatality occurring in any particular year is directly related to the weighted vehicle miles traveled in that year.

Table VI-144 - Vehicle-Mass-Related Fatality Impacts over the Lifetime of MY 1977 - MY 2029 Light-Duty Vehicles, by CAFE Policy Alternative, CAFE Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	-20	-20	-18	-18	-13	-13	-10
Fatality Costs ($ Billion, 3% Discount Rate)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Fatality Costs ($ Billion, 7% Discount Rate)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	-0.2	-0.2	-0.2	-0.2	-0.1	-0.2	-0.1
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Total Crash Costs ($ Billion, 3% Discount Rate)	-0.4	-0.4	-0.3	-0.3	-0.2	-0.2	-0.2
Total Crash Costs ($ Billion, 7% Discount Rate)	-0.2	-0.2	-0.2	-0.2	-0.1	-0.2	-0.1

Table VI-145 - Vehicle-Mass-Related Fatality Impacts over the Lifetime of MY 1977 - MY 2029 Passenger Cars, by CAFE Policy Alternative, CAFE Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	-22	-22	-21	-21	-14	-14	-11
Fatality Costs ($ Billion, 3% Discount Rate)	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1
Fatality Costs ($ Billion, 7% Discount Rate)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	-0.3	-0.3	-0.2	-0.2	-0.2	-0.2	-0.1
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1
Total Crash Costs ($ Billion, 3% Discount Rate)	-0.4	-0.4	-0.4	-0.4	-0.3	-0.3	-0.2
Total Crash Costs ($ Billion, 7% Discount Rate)	-0.3	-0.3	-0.2	-0.2	-0.2	-0.2	-0.1

Table VI-146 - Vehicle-Mass-Related Fatality Impacts over the Lifetime of MY 1977 - MY 2029 Light Trucks, by CAFE Policy Alternative, CAFE Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	2	2	2	2	1	1	1
Fatality Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fatality Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table VI-147 - Vehicle-Mass-Related Fatality Impacts over the Lifetime of MY 1977 - MY 2029 Light-Duty Vehicles, by CAFE Policy Alternative, CO_2 Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	-18	-17	-17	-17	-14	-15	-14
Fatality Costs ($ Billion, 3% Discount Rate)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Fatality Costs ($ Billion, 7% Discount Rate)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.1
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Total Crash Costs ($ Billion, 3% Discount Rate)	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
Total Crash Costs ($ Billion, 7% Discount Rate)	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2

Table VI-148 - Vehicle-Mass-Related Fatality Impacts over the Lifetime of MY 1977 - MY 2029 Passenger Cars, by CAFE Policy Alternative, CO_2 Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	-18	-17	-17	-17	-15	-15	-14
Fatality Costs ($ Billion, 3% Discount Rate)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Fatality Costs ($ Billion, 7% Discount Rate)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Total Crash Costs ($ Billion, 3% Discount Rate)	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
Total Crash Costs ($ Billion, 7% Discount Rate)	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2

Table VI-149 - Vehicle-Mass-Related Fatality Impacts over the Lifetime of MY 1977 - MY 2029 Light Trucks, by CAFE Policy Alternative, CO_2 Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	0	0	0	0	0	0	0
Fatality Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fatality Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

As shown in the tables above, all of the alternatives are estimated to lead to a decrease in the number of mass-related fatalities over the cumulative lifetime of MY 1977-2029 vehicles. The effects of mass changes on fatalities range from a combined decrease (relative to the augural standards, the baseline) of 10 fatalities for Alternative #7 to a combined decrease of 20 fatalities for Alternatives #1 and #2. The difference in results by alternative depends upon how much weight reduction is used in that alternative and the types and sizes of vehicles to which the weight reduction applies. The decreases in fatalities are driven by impacts within passenger cars (decreases of between 11 and 22 fatalities) and are offset by impacts within light trucks (increases of between 1 and 2 fatalities).

Commented [A410]: **REVISE:** Is there a sensitivity analysis to show how much these numbers change if the mass coefficients change?

Changes in vehicle mass are estimated to decrease social safety costs over the lifetime of the nine model years by between $0.2 billion (for Alternative #7) and $0.4 billion (for Alternative #2) relative to the augural standards at a three-percent discount rate and by between $0.1 billion and $0.2 billion at a seven-percent discount rate. The estimated decreases in social safety costs are driven by estimated decreases in costs associated with passenger cars, ranging from $0.2 billion (for Alternative #7) to $0.4 billion (for Alternative #2) relative to the Augural standards at a three-percent discount rate and by between $0.1 billion and $0.3 billion at a seven-percent discount rate. The estimated decreases in costs associated with passenger cars are offset partially by estimated increases in costs associated with light trucks, which are less than $0.1 billion relative to the Augural standards at three-percent and seven-percent discount rates for all policy alternatives.

In this analysis, the profile of mass reduction across vehicle models leads to a small, but beneficial effect on fatalities as fuel economy standards are tightened. Table VI-150Table VI-150 through Table VI-155Table VI-155 present average annual estimated safety effects of vehicle mass changes, for CYs 2035-2045:

Table VI-150 - Comparison of the Calculated Annual Average Vehicle-Mass-Related Fatality Impacts for CY 2035-2045 in Light-Duty Vehicles, by CAFE Policy Alternative, CAFE Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	-3	-3	-3	-3	-2	-2	-1
Fatality Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fatality Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table VI-151 - Comparison of the Calculated Annual Average Vehicle-Mass-Related Fatality Impacts for CY 2035-2045 in Passenger Cars, by CAFE Policy Alternative, CAFE Program Relative to Augural Standards, Fatalities Undiscounted

Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	-4	-4	-3	-3	-2	-2	-2
Fatality Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fatality Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 3% Discount Rate)	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table VI-152 - Comparison of the Calculated Annual Average Vehicle-Mass-Related Fatality Impacts for CY 2035-2045 in Light Trucks, by CAFE Policy Alternative, CAFE Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	0	0	0	0	0	0	0
Fatality Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fatality Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table VI-153 - Comparison of the Calculated Annual Average Vehicle-Mass-Related Fatality Impacts for CY 2035-2045 in Light-Duty Vehicles, by CAFE Policy Alternative, CO_2 Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	-3	-3	-2	-2	-2	-2	-2
Fatality Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fatality Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table VI-154 - Comparison of the Calculated Annual Average Vehicle-Mass-Related Fatality Impacts for CY 2035-2045 in Passenger Cars, by CAFE Policy Alternative, CO_2 Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	-3	-3	-3	-3	-2	-2	-2
Fatality Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fatality Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 3% Discount Rate)	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table VI-155 - Comparison of the Calculated Annual Average Vehicle-Mass-Related Fatality Impacts for CY 2035-2045 in Light Trucks, by CAFE Policy Alternative, CO_2 Program Relative to Augural Standards, Fatalities Undiscounted, Dollars Discounted at 3% and 7%

	Alternative						
	#1	#2	#3	#4	#5	#6	#7
Model Years Affected by Policy	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities	0	0	0	0	0	0	0
Fatality Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fatality Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Non-Fatal Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 3% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Crash Costs ($ Billion, 7% Discount Rate)	0.0	0.0	0.0	0.0	0.0	0.0	0.0

For all light-duty vehicles, mass changes are estimated to lead to an average annual decrease in fatalities in all alternatives evaluated for CYs 2035-2045. The effects of mass changes on fatalities range from a combined decrease (relative to the Augural standards) of 1 fatality per year for Alternative #7 to a combined decrease of 3 fatalities per year for Alternatives #1 through #4. The difference in the results by alternative depends upon how much weight reduction is used in that alternative and the types and sizes of vehicles to which the weight reduction applies. The decreases in fatalities are generally driven by impacts within passenger cars (decreases of between 2 and 4 fatalities per year relative to the Augural standards) and are offset negligibly by impacts within light trucks (increases of less than 1 fatality per year).

Commented [A411]: **REVISE:** What is the significance of a CY analysis here rather than the MY lifetime that is used everywhere else, and the choice of this range of years?

Commented [A412]: **REVISE:** It's confusing that the accounting has changed from a TOTAL fatality change over the lifetime of MODEL years (the previous set of tables) to a PER ANNUM change for certain CALENDAR years (as is used in these tables).

Changes in vehicle mass are estimated to decrease average annual social safety costs in CY 2035-2045 by less than $0.1 billion for all policy alternatives. Average annual social safety costs associated with passenger cars in CY 2035-2045 are estimated to decrease by approximately $0.1 billion, but this effect is partially offset by a corresponding increase in costs associated with light trucks.

To help illuminate effects at the model year level, Table VI-156Table VI-156 presents the lifetime fatality impacts associated with vehicle mass changes for passenger cars, light trucks, and all light-duty vehicles by model year under the preferred alternative, relative to the Augural standards for the CAFE Program. Table VI-157Table VI-157 presents an analogous table for the CO_2 Program.

Table VI-156 - Comparison of Lifetime Vehicle-Mass-Related Fatality Impacts by Model Year for CAFE Program under Preferred Alternative, Relative to Augural Standards, Fatalities Undiscounted

	MY 1977-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	MY 2026	MY 2027	MY 2028	MY 2029	TOTAL
Passenger Cars	0	0	0	0	0	0	-1	-1	-1	-2	-3	-4	-4	-4	-21
Light Trucks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Total	0	0	0	0	0	0	-1	-1	-1	-2	-3	-3	-3	-3	-18

Table VI-157 - Comparison of Lifetime Vehicle-Mass-Related Fatality Impacts by Model Year for CO_2 Program under Preferred Alternative, Relative to Augural Standards, Fatalities Undiscounted

	MY 1977-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	MY 2026	MY 2027	MY 2028	MY 2029	TOTAL
Passenger Cars	0	0	0	0	0	0	-1	-1	-2	-2	-3	-3	-3	-3	-17
Light Trucks	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	0	0	0	0	0	0	-1	-1	-2	-2	-3	-3	-3	-3	-17

Under the preferred alternative, passenger car fatalities associated with mass changes are estimated to decrease relative to the augural standards generally from MY 2022 (decrease of 1 fatality) through MY 2029 (decrease of 4 fatalities). Corresponding estimates of light truck fatalities associated with mass changes are unchanged from the Augural standards.

Table VI-158Table VI-158 and Table VI-159Table VI-159 present estimates of monetized lifetime social safety costs associated with mass changes by model year at three-percent and seven-percent discount rates, respectively for the CAFE Program.

Table VI-160Table VI-160 and Table VI-161Table VI-161 show comparable tables from the perspective of the CO_2 Program.

Table VI-158 - Comparison of Lifetime Social Safety Costs Associated with Mass Changes for CAFE Program by Model Year under Preferred Alternative ($bil.), Relative to Augural Standards, Dollars Discounted at 3%

	MY 1977-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	MY 2026	MY 2027	MY 2028	MY 2029	TOTAL
Passenger Cars	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Light Trucks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1

Table VI-159 - Comparison of Lifetime Social Safety Costs Associated with Mass Changes for CAFE Program by Model Year under Preferred Alternative ($bil.), Relative to Augural Standards, Dollars Discounted at 7%

	MY 1977-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	MY 2026	MY 2027	MY 2028	MY 2029	TOTAL
Passenger Cars	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Light Trucks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1

Table VI-160 - Comparison of Lifetime Social Safety Costs Associated with Mass Changes for CO_2 Program by Model Year under Preferred Alternative ($bil.), Relative to Augural Standards, Dollars Discounted at 3%

	MY 1977-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	MY 2026	MY 2027	MY 2028	MY 2029	TOTAL
Passenger Cars	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Light Trucks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1

Table VI-161 - Comparison of Lifetime Social Safety Costs Associated with Mass Changes for CO_2 Program by Model Year under Preferred Alternative ($bil.), Relative to Augural Standards, Dollars Discounted at 7%

	MY 1977-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	MY 2026	MY 2027	MY 2028	MY 2029	TOTAL
Passenger Cars	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
Light Trucks	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1

Lifetime social safety costs associated with mass change are estimated to be minimal under the preferred alternative. The net estimated effects of mass changes on lifetime social safety costs are less than $0.1 billion for all model years through MY 2029.

b) Impact of Vehicle Prices on Fatalities

The sales and scrappage responses discussed in Chapter XX have important safety consequences and influence safety outcomes through the same basic mechanism, fleet turnover. In the case of the scrappage response, delaying fleet turnover keeps drivers in older vehicles which are less safe than newer vehicles. Similarly, the sales response slows the rate at which newer vehicles, and their associated safety improvements, enter the on-road population. The sales response also influences the mix of vehicles on the road--with more stringent CAFE standards leading to a higher share of light trucks sold in the new vehicle market, assuming all else is equal. Light trucks have higher rates of fatal crashes when interacting with passenger cars and, as earlier sections discussed, different directional responses to mass reduction technology based on the existing mass and body style of the vehicle.[1528]

With an integrated fleet model now part of the analytical framework for CAFE analysis, any effects on fleet turnover (either from delayed vehicle retirement or deferred sales of new vehicles) will affect the distribution of both ages and model years present in the on-road fleet. Because each of these vintages carries with it inherent rates of fatal crashes, and newer vintages are generally safer than older ones, changing that distribution will change the total number of on-road fatalities under each regulatory alternative. Similarly, the dynamic fleet share model captures the changes in the fleet's composition of cars and trucks. As cars and trucks have different fatality rates, differences in fleet composition across the alternatives will affect fatalities.

At the highest level, the agencies calculate the impact of the sales and scrappage effects by multiplying the VMT of a vehicle by the fatality risk of that vehicle. For this analysis, calculating VMT is rather simple: the agencies use the distribution of miles calculated in Section [XX.XX]. The trickier aspect of the analysis is creating fatality rate coefficients. The fatality risk measures the likelihood that a vehicle will be involved in fatal accident per mile driven. As explained below, the agencies' methodology changed from the proposal to this final rule in response to comments, but the basic analytical framework remains the same. The agencies calculate the fatality risk of a vehicle based on the vehicle's model year, age, and style, while controlling for factors which are independent of the intrinsic nature of the vehicle, such as behavioral characteristics.

[1528] *See* Chapter 6.XX for a full explanation of the sales and scrappage effects and how they are modeled.

(1) How the Agencies Modeled Impacts of Vehicle Scrappage and Sales on Fatalities in the NPRM

In the proposal, the sales-scrappage safety model comprised two components.[1529] First, the agencies estimated an empirical relationship among vehicle age, model year or vintage, and fatalities using the FARS database of fatal crashes, vehicle registration data from Polk to represent the on-road vehicle population, and the mileage accumulation schedules discussed in Chapter XX to estimate total vehicle use.[1530] These data were used to construct per-mile fatality rates that varied by vehicle vintage, and also accounted for the influence of vehicle age. To accomplish this, the agencies used FARS data at a lower level of resolution; rather than looking at each crash and the specific factors that contributed to its occurrence, the agencies looked at the total number of fatal crashes involving light-duty vehicles over time with a focus on the influence of vehicle *age* and vehicle *vintage*. The model used in the proposal incorporated a weighted quartic polynomial regression (with each observation weighted by the number of registered vehicles it represented) on vehicle age, and included fixed effects for each model year present in the dataset. The model reproduced the observed fatalities of a given model year, at each age, reasonably well with more recent model years estimated with smaller errors. These estimates were used to account for the inherent safety risks of the legacy fleet and the influence of age on a vehicle's fatality rate.

In the proposal, the agencies noted that factors other than the advent of new safety technologies have affected the historical trend in fatality and injury rates and are likely to continue to do so in the future. These include changes in driver behavior, including seat belt use, driving under the influence of alcohol or drugs, and driver distraction, particularly from the use of hand-held electronic devices such as smartphones, all of which affect either the frequency with which drivers are involved in crashes or the severity of accidents. They also include changes in the demographic composition of driving, since drivers of different ages, gender, income levels, and educational attainment have differing accident-involvement rates, as well as in the geographic distribution of motor vehicle travel, since road and driving conditions (visibility, etc.) tend to be poorer in rural areas than in urban locations, thus leading to more frequent and more severe crashes. Other factors affecting safety trends include infrastructure investments and road maintenance practices that improve road design and travel conditions, thus reducing the frequency and severity of crashes, improvements in accident response and

[1529] The derivation of the NPRM analysis is discussed in detail in Chapter 7 of the FRIA.

[1530] The analysis supporting the CAFE rule for MYs 2017 and beyond did not account for differences in exposure or inherent safety risk as vehicles aged throughout their useful lives. However, the relationship between vehicle age and fatality risk is an important one. In a 2013 Research Note, NHTSA's National Center for Statistics and Analysis (NCSA) concluded a driver of a vehicle that is 4-7 years old is 10% more likely to be killed in a crash than the driver of a vehicle 0-3 years old, accounting for the other factors related to the crash. This trend continued for older vehicles more generally, with a driver of a vehicle 18 years or older being 71% more likely to be killed in a crash than a driver in a new vehicle. "How Vehicle Age and Model Year Relate to Driver Injury Severity in Fatal Crashes," DOT HS 811 825, NHTSA NCSA, August 2013. While there are more registered vehicles that are 0-3 years old than there are 20 years or older (nearly three times as many) because most of the vehicles in earlier vintages are retired sooner, the average age of vehicles in the United States is 11.6 years old and has risen significantly in the past decade. Based on data acquired from Ward's Automotive.

emergency medical care, and cyclical variation in economic activity, which affects the demographic composition of drivers on the road.

Seat belts have historically been the single most effective safety technology, preventing roughly half of all fatalities in the event of a potentially fatal crash, and accounting for over half the lives cumulatively saved by all FMVSS-related safety technologies since 1960.[1531] While belts have been in passenger vehicles since the 1960s, few drivers or passengers initially used them. Over the past 3 decades, seat belt usage rates have steadily climbed from under 60 percent in the early 1990s to roughly 90 percent in 2018 and has been the single most significant factor in reducing fatality rates over time. Additional changes in seat belt use are possible but challenging to achieve, since the last drivers to buckle up are typically the most likely to be risk takers and are often the most resistant to changing their habits. Moreover, with usage rates already at 90 percent, there is less potential for continued improvement.

Overall, the agencies believe improvement in seat belt use is unlikely to have the impact going forward that it has in the past. Technological fixes are possible for seat belt use and impaired driving, but would likely require the promulgation of new regulation, and therefore cannot be assumed. Similarly, individual States could take steps to address impaired driving, speeding, driver distraction, seat belt use and roadway infrastructure improvements, but the pace and impact of such improvements is speculative. The agencies also note that improvements in roadway infrastructure and human factors such as belt and alcohol use potentially affect both old and new vehicles alike. If improvements in these non-vehicle factors are equally spread across vehicles of all MY age groups, the differences in their fatality rates would not change. In other words, these types of improvements might shift the entire MY fatality rate curve down rather than change its slope.

Nonetheless, the agencies stated that it was reasonable to expect some continuation in the generalized trend from non-vehicle technology factors such as these. In the analysis supporting the NPRM, our statistical model controlled for non-vehicle safety factors by accounting for the well-documented fact that older vehicles tend to be owned and driven by drivers whose demographic characteristics, behavior, and geographic location tends are associated with more frequent or severe crashes.

Second, the agencies created estimates of future fatality rates. The agencies noted that predicting future safety trends has an inherent degree of uncertainty, which was amplified due to the dearth of academic and empirical research available at the time of the proposal. Although the agencies expected further safety improvements because of advanced driver assistance systems, such as automatic braking and eventually fully automated vehicles, the pace of development and extent of consumer acceptance of these improvements was uncertain. Thus, instead of attempting to model the impact of future safety features directly, the agencies relied on two different trend models to predict future safety trends. The first model relied on the results from a

[1531] Kahane, C.J., Lives Saved by Vehicle Safety Technologies and Associated Federal Motor Vehicle Safety Standards, 1960 to 2012 – Passenger Cars and LTVs, National Highway Traffic Safety Administration, Paper Number 15-0291. https://www-esv.nhtsa.dot.gov/Proceedings/24/files/24ESV-000291.PDF.

previous NCSA study that measured the effect of known safety regulations on fatality rates by performing statistical evaluations of the effectiveness of motor vehicle safety technologies based on real world performance in the on-road vehicle fleet to determine the effectiveness of each safety technology.[1532] The agencies used this information to forecast future fatality rates. The second model employed was simpler. The agencies used actual, aggregate fatality rates measured from 2000 through 2016 and modeled the fatality rate trend based on these historical data.

The agencies noted that both models had significant limitations and predicted significantly different safety trends. The NCSA study focused on projections to reflect known technology adaptation requirements, but it was conducted prior to the 2008 recession, which disrupted the economy and changed travel patterns throughout the country, and predated the emergence of newer technologies in the 2010s. The NCSA anticipated continued improvement well beyond 2020. By contrast, the historical fatality rate model reflected shifts in safety not captured by the NCSA model, but gave arguably implausible results after 2020 because of an observed upward shift in fatalities between 2014 and 2015. It essentially represented a scenario in which economic, market, or behavioral factors minimize or offset much of the potential impact of future safety technology. To reconcile the two projections of safety improvements beyond 2015, the agencies averaged the NCSA and historical fatality rate models, accepting each as an illustration of different and conflicting possible future scenarios.

The agencies received a number of comments on the provisional model used in the NPRM, which focused mainly on its omission of variables that change over time and can affect the safety of all vehicles in use, regardless of their original model year or current age. As indicated previously, these include changes in seat belt use, driving under the influence of alcohol or drugs, use of hand-held electronic devices, driver demographics, the geographic distribution of vehicle use, road design and maintenance, emergency response and medical care, and overall economic activity.

For example, CARB asserted that the NPRM modeling overestimated fatality rates for older vehicles because it did not "control for factors that can have a significant influence on fatality risk, such as crash circumstances and driver characteristics." Elsewhere, CARB highlighted the omission of calendar year effects from the NPRM analysis, adding "the agencies only model fatality rate as a function of model year, but fatality rate should be a function of both model year and calendar year [...] [which] would account for systematic safety improvements to the entire on-road fleet."[1533] CARB also argued that analysis should account for safety differences between body styles, noting that passenger cars and other LTVs "have historically had different safety regulations."[1534]

Similarly, States and Cities noted the potential importance of factors that can affect trends in vehicle safety over time, pointing out that "increased seat belt use over time, improvements in

[1532] Blincoe, L. and Shankar, U., "The Impact of Safety Standards and Behavioral Trends on Motor Vehicle Fatality Rates," National Highway Traffic Safety Administration, DOT HS 810 777, Washington, D.C., January, 2007.
[1533] CARB, Detailed Comments, NHTSA-2018-0067-11873 at 263.
[1534] CARB, Auken Fatality Report, NHTSA-2018-0067-11881, at 25.

roadway design and life-saving emergency response and treatment, and crash compatibility with other vehicles improve the overall safety of vehicles currently on the road" and therefore concluded that "the CAFE model's assumption that the fatality rate of a 1985 model year vehicle is 23.8 per billion vehicle miles traveled for any calendar year is incorrect. That error increases the risk of fatalities determined by the NPRM for scrappage by around 25 percent."[1535] Consumers Union echoed this argument and suggested driver characteristics and behavior may "more strongly influence fatality risk than a vehicle's model year"[1536].

IPI speculated that omitting the effect of variables that change over time in ways that could affect fleet-wide safety may have caused the agencies' analysis to over-emphasize the role of safety improvements to new vehicles. Specifically, IPI observed that "the agencies could not adequately control for driver behavior trends. And a decrease in fatalities could look like it was caused by vehicle improvements over time rather than societal changes."[1537].

The agencies also received a few comments on their modeling choices. For example, CARB commented that the agencies equation for the legacy fleet was "either incorrect or [had] limited domain-of-validity because it can potentially predict negative fatality rates" and because it was missing an intercept term.[1538] CARB suggested a logarithmic function would fix the problem. The agencies note that the polynomial specification of the safety model the agencies developed for the legacy fleet was extremely unlikely to predict negative fatality rates in light of the estimated values of its coefficients, and that its fixed-effects specification in effect included separate intercept terms for each model year, with that for the earliest model year serving as the "reference case" and thus performing the normal role of the constant term.

(2) Revised Sales-Scrappage Safety Model

In response to the comments, the agencies have taken several steps to revise the sales-scrappage safety model. First, the agencies developed a revised statistical model to explain historical improvements in the lifetime safety performance of each successive new vintage of cars and light trucks, and used the results of this improved model to project the future trend in the overall fatality rates. While the revised historical trend model itself is more complex than the one utilized in the proposal, the overall procedure is simpler; the agencies have collapsed the two piecemeal components discussed above into one model and eliminated the need to 'reconcile' differences between competing future projections. Next, the agencies applied detailed empirical estimates of the market uptake and improving effectiveness of crash avoidance technologies to estimate their effect on the fleet-wide fatality rate, including explicitly incorporating both the direct effect of those technologies on the crash involvement rates of new vehicles equipped with them, as well as the "spillover" effect of those technologies on improving the safety of occupants of vehicles that are not equipped with these technologies.

[1535] States and Cities. However, this commenter provided no source for its estimate that the agency may have overstated the effect of changes in vehicle scrappage patterns on fatalities by 25%.
[1536] Consumers Union, [complete citation].
[1537] IPI, NHTSA-2018-0067-12213, at 71.
[1538] CARB, Auken Fatality Report, NHTSA-2018-0067-11881, at 25.

(a) Crash Avoidance

In the NPRM, the agencies took a very generalized approach to estimating the pace of future safety trends. For reasons discussed above, the agencies noted that there was uncertainty regarding actual trends in fatality rates. This issue was addressed by numerous commenters who took opposing positions. Among them, IPI stated that "[t]he agencies have not provided an adequate explanation for why past safety trends are likely to continue until the mid-2020s." IPI further noted that "crash avoidance technology may not be adopted as easily or readily as crash mitigation technologies have been."[1539] In response, the agencies note that the trend the agencies adopted for the NPRM was not a direct continuation of past trends. Rather, it was a simple average of several possible models the agencies had examined, accepting each as an illustration of different and conflicting possible future scenarios.

By contrast, States and Cities asserted that fatality rates may be lower in the future than the agencies estimated, noting that the NPRM analysis did not "account for safety benefits that new safety technologies in future vehicles will have on the agencies predicted outcome."[1540] While the agencies agree that the NPRM analysis did not analyze individual safety benefits of new technologies, the trends included in the NPRM were intended, in part, as a proxy estimate of the impact of these technologies. As discussed in the NPRM, these technologies were cited as a justification for assuming a continued downward trend in the fatality rate through roughly 2035.

Nonetheless, the agencies believe that further analysis of these potential trends can now be ascertained for several explicit technologies. In response to comments suggesting that the agencies account more directly for new safety technologies, the agencies augmented the sales-scrappage safety analysis for the final rule with recent research into the effectiveness of specific advanced crash avoidance safety technologies that are expected to drive future safety improvement to estimate the impacts of crash avoidance technologies. The analysis analyzes six crash avoidance technologies that are currently being produced and commercially deployed in the new vehicle fleet. These include Frontal Collision Warning (FCW), Automatic Emergency Braking (AEB), Lane Departure Warning (LDW), Lane Keep Assist (LKA), Blind Spot Detection (BSD), and Lane Change Alert (LCA).[1541] These are the principal technologies that are being developed and adopted in new vehicle fleets and will likely drive vehicle-based safety improvements for the coming decade. These technologies are being installed in more and more new vehicles; in fact, manufacturers recently reported that they voluntarily installed AEB systems in approximately 70 percent of new vehicles sold in the year ending August 30, 2019. [CITE to NHTSA report] The agencies note that the terminology and the detailed characteristics of these systems may differ across manufacturers, but the basic system functions are common across all.

These 6 technologies address three basic crash scenarios through warnings to the driver or alternately, through dynamic vehicle control:

[1539] IPI, Appendix, NHTSA-2018-0067-12213, at 98.
[1540] States and Cities, Detailed Comments, NHTSA-2018-0067-11735, at 80.
[1541] A full description of these technologies and several other technologies referenced below may be found in the FRIA Chapter [XX.XX].

1. Forward collisions, typically involving a crash into the rear of a stopped vehicle;
2. Lane departure crashes, typically involving inadvertent drifting across or into another traffic lane; and
3. Blind spot crashes, typically involving intentional lane changes into unseen vehicles driving in or approaching the driver's blind spot.

Unlike traditional safety features where the bulk of the safety improvements were attributable to improved protection when a crash occurs (crash worthiness), the impact of advanced crash avoidance technologies (ADAS or advanced driver assistance systems) will have on fatality and injury rates is a direct function of their effectiveness in preventing or reducing the severity of the crashes they are designed to mitigate. This effectiveness is typically measured using real world data comparing vehicles with these technologies to similar vehicles without them. While these technologies are actively being deployed in new vehicles, their penetration in the larger on-road vehicle fleet has been at a low, but growing level. This limits the precision of statistical regression analyses, at least until the technologies become more common in the on-road fleet.

Our approach in the final rule is to derive effectiveness rates for these advanced crash-avoidance technologies from safety technology literature. The agencies then apply these effectiveness rates to specific crash target populations for which the crash avoidance technology is designed to mitigate and adjusted to reflect the current pace of adoption of the technology, including the public commitment by manufactures to install these technologies. The products of these factors, combined across all 6 advanced technologies, produce a fatality rate reduction percentage that is applied to the fatality rate trend model discussed below, which projects both vehicle and non-vehicle safety trends. The combined model produces a projection of impacts of changes in vehicle safety technology as well as behavioral and infrastructural trends.

(i) Technology Effectiveness Rates

Forward Crash Collision Technologies

For forward collisions, manufacturers are currently equipping vehicles with FCW, which warns drivers of impending collisions, as well as AEB, which incorporates the sensor systems from FCW together with dynamic brake support (DBS) and crash imminent braking (CIB) to help avoid crashes or mitigate their severity. Manufacturers have committed voluntarily to install some form of AEB on all light vehicles by the 2023 model year (September 2022).[1542]

Table VI-162Table VI-162 summarizes studies which have measured effectiveness for various forms of FCW and AEB over the past 13 years. Most studies focused on crash reduction rather than injury reduction. This is a function of limited injury data in the on-road fleet, especially during the early years of deployment of these technologies. In addition, it reflects engineering limitations in the technologies themselves. Initial designs of AEB systems were basically incapable of detecting stationary objects at speeds higher than 30 mph, making them potentially ineffective in higher speed crashes that are more likely to result in fatalities or serious

[1542] *See* https://www.nhtsa.gov/press-releases/nhtsa-iihs-announcement-aeb.

injury. For example, Wiacek et al. (2-15) conducted a review of rear-end crashes involving a fatal occupant in the 2003-2012 NASS-CDS data-bases to determine the factors that contribute to fatal rear-end crashes.[1543] They found that the speed of the striking vehicle was the primary factor in 71 percent of the cases they examined. The average Delta-V of the striking vehicle in these cases was 46 km/h (28.5 mph), implying pre-crash travel speeds in excess of this speed. While Table VI-162Table VI-162 includes studies going back to 2005, the agencies focus our discussion on more recent studies conducted after 2012 in order to reflect more current safety systems and vehicle designs.

Table VI-162 - Summary of AEB Technology Effectiveness Estimates

				Injury Reduction		
Authors	**AEB Type**	**Crashes**	**Fatalities**	**Serious**	**Minor**	**All Injuries**
Sugimoto & Sauer (2005)[1544]	CMBS	38%	44%			
Page et al (2005)[1545]	EBA		7.50%			11%
Najm et al (2005)[1546]	ACAS	6-15%				
Breuer et al (2007)[1547]	BAS+	44%				
Kuehn et al (2009)[1548]	CMBS	40.80%				
Grover et al (2008)[1549]	AEB	30%				

[1543] Wiacek, C., Bean, J., Sharma, D., *Real World Analysis of Fatal Rear-End Crashes*, National Highway Traffic Safety Administration, 24th Enhanced Safety of Vehicles Conference, 150270, 2015.

[1544] Sugimoto, Y., and Sauer, C., (2005). Effectiveness Estimation Method for Advanced Driver Assistance System and its Application to Collision Mitigation Brake systems, paper number 05-148, 19th International Technical Conference on the Enhanced safety of Vehicles (ESV), Washington D.C., June 6-9, 2005.

[1545] Page, Y., Foret-Bruno, J., & Cuny, S. (2005). Are expected and observed effectiveness of emergency brake assist in preventing road injury accidents consistent?, 19th ESV Conference, Washington DC.

[1546] Najm, W.G., Stearns, M.D., Howarth, H., Koopman, J. & Hitz, J., (2006). Evaluation of an Automotive Rear-End Collision Avoidance System (technical report DOT HS 810 569), Cambridge, MA: John A. Volpe National Transportation System Center, U.S. Department of Transportation.

[1547] Breuer, JJ., Faulhaber, A., Frank, P. and Gleissner, S. (2007). Real world Safety Benefits of Brake Assistance Systems, Proceedings of the 20th International Technical Conference of the Enhanced Safety of Vehicles (ESV) in Lyon, France June 18-21, 2007.

[1548] Keuhn, M., Hummel, T., and Bende J., Benefit estimation of advanced driver assistance systems for cars derived from real-world accidents, Paper No. 09-0317, 21st International Technical Conference on the Enhanced Safety of Vehicles (ESV) – International Congress Centre, Stuttgart, Germany, June 15-18, 2009.

[1549] Grover, C., Knight, I., Okoro, F., Simmons I., Couper, G., Massie, P., and Smith, B, (2008). Automated Emergency Brake Systems: Technical requirements, Costs and Benefits, PPR227, TRL Limited, DG Enterprise, European Commission, April 2008.

Kisano &Gabler (2015)[1550]	AEB	0-67%	2-69%	2-69%		
HLDI (2011)[1551]	AEB	22-27%				51%
Doecke et al (2012)[1552]	AEB	25-28%				
Chauvel et al (2013)[1553]	PAEB	4.30%	15%	37%		
Fildes et al (2015)[1554]	AEB	38%				
Cicchino (2017)[1555]	FCW	27%				20%
	AEB	50%				56%
Kusano & Gabler (2012)[1556]	FCW	3.20%	29%	29%		
	AEB	7.70%	50%	50%		
Flannagan & Leslie (2018)[1557]	FCW	16%				
	AEB	45%				

Doecke et al. (2012) created simulations of 103 real world crashes and applied AEB system models with differing specifications to determine the change in impact speed that various AEB interventions might produce. Their modeling found significant rear-end crash speed reductions with various AEB performance assumptions. In addition, they estimated a 29 percent

[1550] Kusano, K.G., and Gabler, H.C. (2015). Comparison of Expected Crash Injury and Injury Reduction from Production Forward Collision and Lane Departure Warning Systems, Traffic Injury Prevention 2015; Suppl. 2: S109-14.

[1551] HLDI (2011). Volvo's City Safety prevents low-speed crashes and cuts insurance costs. Status Report, Vol. 46, No. 6, July 19,2011.

[1552] Docke, S.D., Anderson, R.W.G., Mackenzie ,J.R.R., Ponte, G. (2012). The potential of autonomous emergency braking systems to mitigate passenger vehicle crashes. Australian Road Safety Research Policing and Education Conference, October 4-6, 2012, Wellington, New Zealand.

[1553] Chauvel, C., Page, Y., Fildes, B.N., and Lahausse, J. (2013). Automatic emergency braking for pedestrians effective target population and expected safety benefits, Paper No. 13-0008, 23rd International Technical Conference on the Enhanced Safety of Vehicles (ESV), Seoul, Republic of Korea, May 27-30, 2013.

[1554] Fildes B., Keall M., Bos A.,Lie A., Page, Y., Pastor, C., Pennisi, L., Rizzi ,M., Thomas, P., and Tingvall, C. Effectiveness of Low Speed Autonomous Emergency Braking in Real-World Rear-End Crashes. Accident Analysis and Prevention, AAP-D-14-00692R2.

[1555] Cicchino, J.B. (2017). Effectiveness of forward collision warning and autonomous emergency braking systems in reducing front-to-rear crash rates. Accident Analysis and Prevention, V. 99, Part A, February 2017, Pages 142-52.

[1556] Kusano, K.D., and Gabler H.C. (2012). Safety Benefits of Forward Collision Warning, Brake Assist, and Autonomous Braking Systems in Rear-End Collisions, Intelligent Transportation Systems, IEEE Transactions, Volume 13 (4).

[1557] Flannagan, C. and Leslie, A. (2018). Crash Avoidance Technology Evaluation Using Real-World Crashes. University of Michigan Transportation Research Institute, Final Report, March 22, 2018.

reduction in rear-end crashes and that 25 percent of crashes over 10 km/h were reduced to 10 km/h or less.

Cicchino (2016) analyzed the effectiveness of a variety of forward collision mitigation systems including both FCW and AEB systems. Cicchino used a Poisson regression to compare rates of police-reported crashes per insured vehicle year between vehicles with these systems and the same models that did not elect to install them. The analysis was based on crashes occurring during 2010 to 2014 in 22 States and controlled for other factors that affected crash risk. Cicchino found that FCW reduced all rear-end striking crashes by 27 percent and rear-end striking injury crashes by 20 percent, and that AEB functional at high-speeds reduced these crashes by 50 and 56 percent, respectively. She also found that low speed AEB without driver warning reduced all crashes by 43 percent and injury crashes by 45 percent. She also found that even low-speed AEB could impact crashes at higher speed limits. Reductions were found of 53 percent, 59 percent, and 58 percent for all rear-end striking crash rates, rear-end striking injury crash rates, and rear-end third party injury crash rates, respectively, at speed limits of 40-45 mph. For speed limits of 35 mph or less, reductions of 40 percent, 40 percent, and 43 percent were found. For speed limits of 50 mph or greater, reductions of 31 percent, 30 percent, and 28 percent, were found. Further, Cicchino (2016) found significant reductions (30 percent) in rear-end injury crashes even in crashes on roadways where speed limits exceeded 50 mph.

Kusano and Gabler (2012) examined the effectiveness of various levels of forward collision technologies including FCW and AEB based on simulations of 1,396 real world rear end crashes from 1993-2008 NASS CDS data-bases. The authors developed a probability-based framework to account for variable driver responses to the warning systems. Kusano and Gabler found FCW systems could reduce rear-end crashes by 3.2 percent and driver injuries in rear-end crashes by 29 percent. They also found that full AEB systems with FCW, pre-crash brake assist, and autonomous pre-crash braking could reduce rear-end crashes by 7.7 percent and reduce moderate to fatal driver injuries in rear-end crashes by 50 percent.

Fildes et al. (2015) performed meta-analyses to evaluate the effectiveness of low-speed AEB technology in passenger vehicles based on real-world crash experience across six different predominantly European countries. Data from these countries was pooled into a standard analysis format and induced exposure methods were used to control for extraneous effects. The study found a 38 percent overall reduction in rear-end crashes for vehicles with AEB compared to similar vehicles without this technology. The study also found no statistical evidence for any difference in effectiveness between urban roads with speed limits less than or equal to 60 km/h, and rural roads with speed limits greater than 60 km/h. Fildes et al. (2015) found no statistical difference in the performance of AEBs on lower speed urban or higher speed rural roadways.

Kusano and Gabler (2015) simulated rear-end crashes based on a sample of 1,042 crashes in the 2012 NASS-CDS. Modelling was based on 54 model year 2010-2014 vehicles that were evaluated in NHTSA's New Car Assessment Program (NCAP). Kusano and Gabler found FCW systems could prevent 0-67 percent of rear-end crashes and 2-69 percent of serious to fatal driver injuries.

Flannagan and Leslie (2018) analyzed the relative crash performance of 35,401 General Motors (GM) MY 2013 to 2015 vehicles linked to State police-reported crashes by Vehicle Identification numbers (VIN). GM provided VIN-linked safety content information for these vehicles to enable precise identification of safety technology content. The authors analyzed the effectiveness of a variety of crash avoidance technologies including both FCW and AEB separately. They estimated effectiveness comparing system-relevant crashes to baseline (control group) crashes using a quasi-induced exposure method in which rear-end struck crashes are used as the control group. Flannagan and Leslie found that FCW reduced rear-end striking crashes of all severities by 16 percent, and that AEB (which includes FCW) reduced these crashes by 45 percent.[1558]

For this analysis, the agencies based their projections on Flannagan and Leslie because they are the most recent study, and thus reflect the most current versions of these systems in the largest number of vehicles, and also because they arguably have the most precise identification of the presence of the specific technologies in the vehicle fleet. Furthermore, Flannagan and Leslie was the only study to report estimates for each of the six crash avoidance technologies analyzed for the final rule, hence providing a certain level of consistency amongst estimates. The agencies recognize that there is uncertainty in estimates of these technologies effectiveness, especially at this early stage of deployment. For this reason, the agencies examine a range of effectiveness rates to estimate boundary outcomes in a sensitivity analysis.

Flannagan and Leslie measured effectiveness against all crashes, but did not specify effectiveness against crashes that result in fatalities or injuries. The agencies will examine a range of effectiveness rates against fatal crashes using a central case as well as boundary sensitivity cases. Our boundary cases will be an assumption of no effectiveness, and an assumption of full effectiveness across all crash types. Our central case will assume a simple average of these two extremes. Flannagan and Leslie found effectiveness rates of 16 percent for FCW and 45 percent for AEB. Our central fatality effectiveness estimates will thus be 8 percent for FCW and 22.5 percent for AEB. The agencies note that our central estimate is conservative

[1558] The agencies note that UMTRI, the sponsoring organization for the Flannagan and Leslie study, published a revised version of the same study in September of 2019, which NHTSA only became aware of in November of 2019 after preparation of the final rule was nearing completion. *See* https://deepblue.lib.umich.edu/bitstream/handle/2027.42/150660/UMTRI-2019-6%20FINAL%20.pdf?sequence=1&isAllowed=y. The revised study uses the same basic techniques but incorporated a larger data-base of system-relevant and control cases. Relative to the Flannagan and Leslie (2018) findings, the results of the study varied by technology. The revised study found effectiveness rates of 21% for FCW and 46% for AEB, compared to 16% and 45% in the 2018 study. The revised study found effectiveness rates of 10% for LDW and 20% for LKA, compared to 3% and 30% for these technologies in the 2018 study. The revised study found effectiveness rates of 3% for BSD and 26-37% for LCA systems, compared to 8% and 19-32% for these technologies in the 2018 study. Thus, some system effectiveness estimates increased while others decreased. Although the agencies are unable to incorporate these estimates into the agencies' baseline calculations, the agencies note that the range of effectiveness rates the agencies' examine in our sensitivity analysis encompasses all results from the new 2019 study with the exception of those for FCW and AEB. AEB is the most influential of these braking technologies and the 2019 study results are nearly identical to the 2018 results (46% vs. 45%). The agencies also note that the central effectiveness estimates used for the analysis remain well below those found in the 2019 study.

compared to averages of those studies that did specifically examine fatality impacts; that is, the analysis assumes reduced future fatalities less than most of, or the average of, those studies, and thus minimizes the estimate of lives saved under alternatives to the augural standards. Furthermore, the agencies note that the estimates against fatal crashes is higher in the recent studies in Table VI-163, which reflects the agencies' understanding that earlier iterations of AEB and FCW may have been less effective against crashes that result in fatalties than newer and improved versions.[1559]

Lane Departure Crash Technologies

For lane departure crashes, manufacturers are currently equipping vehicles with lane departure warning (LDW), which monitors lane markings on the road and alerts the driver when their vehicle is about to drift beyond a delineated edge line of their current travel lane, as well as lane keep assist (LKA), which provides gentle steering adjustments to help drivers avoid unintentional lane crossing. Table VI-164Table VI-164 summarizes studies which have measured effectiveness for LDW and LKA

Table VI-164 - Summary of LDW Technology Effectiveness Estimates

				Injury Reduction		
Authors	**LDW Type**	**Crash Reduction**	**Fatalities**	**Serious**	**Minor**	**All Injuries**
Cicchino (2018)[1560]	LDW	11%				21%
Sternlund, Strandroth, et al (2017)[1561]	LDW/LKA					6-30%
Flannagan & Leslie (2018)[1562]	LDW	3%				
	LKA	30%				
Kusano & Gabler (2015)[1563]	LDW	11-23%	13-22%	13-22%		
Kusano, Gorman, et al (2014)[1564]	LDW	29%		24%		

Cicchino (2018) examined crash involvement rates per insured vehicle year for vehicles that offered LDW as an option and compared crash rates for those that had the option installed to

[1559] As an example of improvements, the agencies note that the Mercedes system described in their 2015 owner's manual specified that for stationary objects the system would only work in crashes below 31 mph, but that in their manual for the 2019 model, the systems are specified to work in these crashes up to 50 mph.
[1560] Cicchino, J.B. (2018). Effects of lane departure warning on police-reported crash rates, Journal of Safety Research 66 (2018), pp.61-70. National Safety Council and Elsevier Ltd., May, 2018.
[1561] Sternlund, S., Strandroth, J., Rizzi, M., Lie, A., and Tingvall, C. (2017). The effectiveness of lane departure warning systems – A reduction in real-world passenger car injury crashes. Traffic Injury Prevention V. 18 Issue 2 Jan 2017.
[1562] Flannagan and Leslie (2018), op. cit.
[1563] Kusano and Gabler (2015), op. cit.
[1564] Kusano, K., Gorman, T.I., Sherony, R., and Gabler, H.C. Potentialoccupant injury reduction in the U.S. vehicle fleet for lane departure warning-equipped vehicles in single-vehicle crashes. Traffic Injury Prevention 2014 Suppl 1:S157-64.

those that did not. The study focused on single-vehicle, sideswipe, and head-on crashes as the relevant target population for LDW effectiveness rates. The study examined 5,433 relevant crashes of all severities found in 2009-2015 police-reported data from 25 States. The study was limited to crashes on roadways with 40 mph or greater speed limits not covered in ice or snow since lower travel speeds would be more likely to fall outside of the LDW systems' minimum operational threshold. Cicchino found an overall reduction in relevant crashes of 11 percent for vehicles that were equipped with LDW. She also found a 21 percent reduction in injury crashes. The result for all crashes was statistically significant, while that for injury crashes approached significance ($p<0.07$). Cicchino did not separately analyze LKA systems.

Sternlund et al. (2017) studied single vehicle and head-on injury crash involvements relevant to LDW and LKA in Volvos on Swedish roadways. They used rear-end crashes as a control and compared the ratio of these two crash groups in vehicles that had elected to install LDW or LCA to the ratio in vehicles that did not have this content. Studied crashes were limited to roadways with speeds of 70-120 kph and not covered with ice or snow. Sternlund et al. found that LDW/LKA systems reduced single vehicle and head-on injury crashes in their crash population by 53 percent, with a lower limit of 11 percent, which they determined corresponded to a reduction of 30 percent (lower limit of 6 percent) across all speed limits and road surface assumptions.

Flannagan and Leslie (2018) analyzed the relative crash performance of 35,401 General Motors (GM) MY 2013 to 2015 vehicles linked to state police-reported crashes by Vehicle Identification numbers (VIN). GM provided VIN-linked safety content information for these vehicles to enable precise identification of safety technology content. The authors analyzed the effectiveness of a variety of crash avoidance technologies including both LDW and LKA separately. They estimated effectiveness comparing system-relevant crashes to baseline (control group) crashes using a quasi-induced exposure method in which rear-end struck crashes are used as the control group. Flannagan and Leslie found that LDW reduced lane departure crashes of all severities by 3 percent (non-significant), and that LKA (which includes LDW) reduced these crashes by 30 percent.

Kusano et al (2014) developed a comprehensive crash and injury simulation model to estimate the potential safety impacts of LDW. The model simulated results from 481 single-vehicle collisions documented in the NASS-CDS data-base for the year 2012. Each crash was simulated as it actually occurred and again as it would occur had the vehicles been equipped with LDW. Crashes were simulated multiple times to account for variation in driver reaction, roadway, and vehicle conditions. Kusano et al found that LDW could reduce all roadway departure crashes caused by the driver drifting from his or her lane by 28.9 percent, resulting in 24.3 percent fewer serious injuries.

Kusano and Gabler (2015), simulated single-vehicle roadway departure crashes based on a sample of 478 crashes in the 2012 NASS-CDS. Modelling was based on 54 model year 2010-2014 vehicles that were evaluated in NHTSA's New Car Assessment Program (NCAP). Kusano and Gabler found LDW systems could prevent 11-23 percent of drift-out-of-lane crashes and 13-22 percent of serious to fatally injured drivers.

As noted previously for frontal crash technologies, the agencies will base our projections on Flannagan and Leslie because they are the most recent study, thereby reflecting the most current versions of these systems in the largest number of vehicles, and because they arguably have the most precise identification of the presence of the specific technologies in the vehicle fleet. However, unlike forward crash technologies, lane change technologies are operational at travel speeds where fatalities are likely to occur. Both LDW and LKA typically operate at speeds above roughly 35 mph. For this reason, and because the research noted in Table VI-164Table VI-164 indicates similar effectiveness against fatalities, injuries, and crashes, the agencies believe it is reasonable to assume the Flannagan & Leslie crash reduction estimates are generally applicable to all crash severities, including fatal crashes. Our central effectiveness estimates are thus 3 percent for LDW and 30 percent for LKA. For sensitivity analysis, the agencies adopt the 95 percent confidence intervals from Flannagan & Leslie. For LKA this range is 4-49 percent. For LDW, the upper range was 10 percent, but the findings were not statistically significant. The agencies therefore limit the range to 0-10 percent.

Blind Spot Crash Technologies

To address blind spot crashes, manufacturers are currently equipping vehicles with BSD, which detects vehicles in either of the adjacent lanes that may not be apparent to the driver. The system warns the driver of an approaching vehicle's presence to help facilitate safe lane changes and avoid crashes. A more advanced version of this, LCA, also detects vehicles that are rapidly approaching the driver's blind spot. Table VI-165Table VI-165 summarizes studies which have measured effectiveness for BSD and LCA.

Table VI-165 - Summary of BSD Technology Effectiveness Estimates

				Injury Crash Reduction		
Authors	**BSD Type**	**Crash Reduction**	**Fatalities**	**Serious**	**Minor**	**Injuries**
Cicchino (2017b)[1565]	BSD	14%				23%
Flannagan & Leslie (2018)[1566]	BSD	8%				
	LCA	32%				
Isaksson-Hellman & Lindman (2018)[1567]	LCA	30%*				31%**
* reduction in claim costs across all lane change crashes						
** reduction in severe crashes with repair costs greater than $1250						

Cicchino (2017) used Poisson regression to compare crash involvement rates per insured vehicle year in police-reported lane-change crashes in 26 U.S. States during 2009-2015 between

[1565] Cicchino, J.B. (2017b). Effects of blind spot monitoring systems on police-reported lane-change crashes. Insurance Institute for Highway Safety, August 2017.
[1566] Flannagan and Leslie (2018), op. cit.
[1567] Isaksson-Hellman, I., Lindman, M., An evaluation of the real-world safety effect of a lane change driver support system and characteristics of lane change crashes based on insurance claims. Traffic Injury Prevention, February 28, 2018: 19 (supp. 1).

vehicles with blind spot monitoring and the same vehicle models without the optional system, controlling for other factors that can affect crash risk. Systems designs across the 10 different manufacturers included in the study varied regarding the extent to which the size of the adjacent lane zone that they covered exceeded the blind spot area, speed differentials at which vehicles could be detected, and their ability to detect rapidly approaching vehicles, but these different systems were not examined separately. The study examined 4,620 lane change crashes, including 568 injury crashes. Cicchino found an overall reduction of 14 percent in blind spot related crashes of all severities, with a non-significant 23 percent reduction in injury crashes.

Flannagan and Leslie (2018) analyzed the relative crash performance of 35,401 2013-2015 General Motors (GM) vehicles linked to State police-reported crashes by Vehicle Identification numbers (VIN). GM provided VIN-linked safety content information for these vehicles to enable precise identification of safety technology content. The authors analyzed the effectiveness of a variety of crash avoidance technologies including both BSD and LCA separately. They estimated effectiveness comparing system-relevant crashes to baseline (control group) crashes using a quasi-induced exposure method in which rear-end struck crashes are used as the control group. Flannagan and Leslie found that BSD reduced lane departure crashes of all severities by 8 percent (non-significant), and that LCA (which includes BSD) reduced these crashes by 32 percent.

Isaksson-Hellman and Lindman (2018) evaluated the effect of the Volvo Blind Spot Information System (BLIS) on lane change crashes. Volvo's BLIS functions as an LCA, detecting vehicles approaching the blind spot as well as those already in it. The authors analyzed crash rate differences in lane change situations for cars with and without the BLIS system based on a population of 380,000 insured vehicle years. The authors found the BLIS system did not significantly reduce the overall number of lane change crashes of all severities, but they did find a significant 31 percent reduction in crashes with a repair cost exceeding $1250, and a 30 percent lower claim cost across all lane change urashes, indicating a reduced crash severity effect.

Like lane change technologies, blind spot technologies are operational at travel speeds where fatalities are likely to occur. The agencies therefore assume the Flannagan & Leslie crash reduction estimates are generally applicable to all crash severities, including fatal crashes. Our central effectiveness estimates are thus 8 percent for BSD and 32 percent for LCA. For sensitivity analysis, the agencies adopt the 95 percent confidence intervals from Flannagan & Leslie. For LCA this range is 14-46 percent. For BSD, the upper range was 25 percent, but the findings were not statistically significant. The agencies therefore limit the range to 0-25 percent.

(ii) Target Populations for Crash Avoidance Technologies

The impact on fatality rates that will occur due to these technologies will be a function of both their effectiveness rate and the portion of occupant fatalities that occur under circumstances that are relevant to the technologies function. The agencies base our target population estimates on a recent study that examined these portions specifically for a variety of crash avoidance technologies including those analyzed here. Wang (2019) documented target populations for five groups of collision avoidance technologies in passenger vehicles including forward

collisions, lane keeping, blind zone detection, forward pedestrian impact, and backing collision avoidance. The first three of these affect the light occupant target population examined in this analysis. Wang separately examined crash populations stratified by severity including fatal injuries, non-fatal injuries, and property damaged only (PDO) vehicles. She based her analysis on 2011-2015 data from NHTSA's Fatality Analysis Reporting System (FARS), National Automotive Sampling System (NASS), and General Estimates System (GES). FARS data was the basis for fatal crashes while nonfatal injuries and PDOs were derived from the NASS and GES.

Wang followed the pre-crash typology concept initially developed by the Volpe National Transportation Systems Center (Volpe). Under this concept, crashes are categorized into mutually exclusive and distinct scenarios based on vehicle movements and critical events occurring just prior to the crash. Table VI-166Table VI-166 summarizes the portion of total annual crashes and injuries for each crash severity category that is relevant to the three crash scenarios examined.

Table VI-166 - Summary of Target Crash Proportions by Technology Group

Safety System Crash Type	Crashes	Fatalities	MAIS 1-5 Injuries	PDOVs
Frontal Crashes	29.4%	3.8%	31.5%	36.3%
Lane Departure Crashes	19.4%	44.3%	17.1%	11.9%
Blind Spot Crashes	8.7%	1.6%	6.7%	11.8%

The relevant proportions vary significantly depending on the severity of the crash. The rear-end crashes that are addressed by FCW and AEB technologies tend to be low-speed crashes and thus account for a larger portion of non-fatal injury and PDO crashes than for fatalities. Only 4 percent of fatal crashes occur in front-to-rear crashes, but over 30 percent of nonfatal crashes are this type. By contrast, fatal crashes are highly likely to involve inadvertent lane departure, 44 percent of all light vehicle occupant fatalities occur in crashes that involve lane departure, but only 17 percent of non-fatal injuries and 12 percent of PDOs involve this crash scenario. Blind spot crashes account for only about 2 percent of fatalities, 7 percent of MAIS1-5 injuries, and 12 percent of PDOs.

The target population of this analysis is occupants of the light vehicles subject to CAFE. The values in Table VI-166Table VI-166 are portions of all crashes that occur annually. These include crashes of motor vehicles not subject to the current CAFE rulemaking such as medium and large trucks, buses, motorcycles, bicycles, etc. To adjust for this, the values in Wang were normalized to represent their portion of all light passenger vehicle (PV) crashes, rather than all crashes of any type. Wang provides total PV fatalities consistent with her technology numbers which are used as a baseline for this process. Based on 2011-2015 FARS data, Wang found an average of 29,170 PV occupant fatalities occurred annually.

A second adjustment to Wang's results was made to make them compatible with the effectiveness estimates found in Flannagan and Leslie. In her target population estimate for lane

departure warning, Wang included both head-on collisions and rollovers, but Flannagan did not. The Flannagan & Leslies effectiveness rate is thus applicable to a smaller target population than that examined by Wang. To make these numbers more compatible, counts for these crash types were removed from Wang's lane departure totals.

Electronic Stability Control (ESC) has been standard equipment in all light vehicles in the US since the 2012 model year. ESC is highly effective in reducing roadway departure and traction loss crashes, and although it will be present in all future model year vehicles, it was present in only about 30 percent of the 2011-2015 on-road fleet examined by Wang. To reflect the impact of ESC on future on-road fleets therefore, the agencies further adjusted Wang's numbers to reflect a 100 percent ESC presence in the on-road fleet. The agencies allocated the reduced roadway departure fatalities to the LDW target population, and the reduced traction loss fatalities to the AEB target population. This has the effect of reducing the total fatalities in both groups as well as in the total projected fatalities baseline.

Table VI-167Table VI-167 summarizes the revised incidence counts and re-calculated proportions of total PV occupant crash /injury. Revised totals are derived from original totals referenced in Table 1-3 in Wang (2019).

Table VI-167 - Adjusted Target Crash Counts and Proportions

Crash Type	Crashes	Fatalities	MAIS 1-5	PDOVs
Frontal Crashes	1,703,541	1,048	883,386	2,641,884
% All PV Occupant Crashes	30.2%	4.0%	32.4%	36.8%
Lane Departure Crashes	1,126,397	9,428	479,939	863,213
% All PV Occupant Crashes	20.0%	35.8%	17.6%	12.0%
Blind Spot Crashes	503,070	542	188,304	860,726
% All PV Occupant Crashes	8.9%	2.1%	6.9%	12.0%
Total, all Tech Groups	3,333,008	11,017	1,551,629	4,365,823
% All PV Occupant Crashes	59.1%	41.8%	56.8%	60.9%
All Crashes	5,640,000	26,364	2,730,000	7,170,000

(iii) Fleet Penetration Schedules

The third element of the rule's safety projections is the fleet technology penetration schedules. Advanced safety technologies (ADAS) will only influence the safety of future MY fleets to the extent that they are installed and used in those fleets. These technologies are already being installed on some vehicles to varying degrees, but the agencies expect that over time, they will become standard equipment due to some combination of market pressure and/or safety regulation. The agencies adopt this assumption based on the history of most previous vehicle safety technologies, which are now standard equipment on all new vehicles sold in the US.

The pace of technology adoption is estimated based on a variety of factors, but the most fundamental is the current pace of adoption in recent years. These published data were obtained from Ward's Automotive Reports for each technology.[1568] Since these technologies are relatively recent, only a few years of data—typically 2 or 3 years—were available from which to derive a trend. This makes these projections uncertain, but under these circumstances, a continuation of the known trend is the baseline assumption, which the agencies modify only when there is a rationale to justify it.

The technologies were examined in pairs reflecting their mutual target populations. Both FCW and AEB affect the same target population—frontal collisions. Both systems have been installed in some current MY vehicles, but their relative paces are expected to diverge significantly due to a formal agreement brokered by NHTSA and IIHS involving nearly all auto manufacturers, to have AEB installed in 100 percent of their vehicles by September 2022 (MY 2023).[1569] Wards first published installation rates for FCW and AEB for the 2016 model year and as of this analysis the 2017 MY is the latest data they have published. The agencies thus have data indicating that FCW was installed in 17.6 percent of MY 2016 vehicles and 30.5 percent of MY 2017 vehicles. AEB was installed in 12.0 percent of MY 2016 vehicles and 27.0 percent of MY 2017 vehicles. AEB was installed in 12.0 percent of MY 2016 vehicles and 27.0 percent of MY 2017 vehicles. More recent reports submitted by manufacturers to the Federal Register indicate that installation rates accelerated in MY 2018 and 2019 vehicles. Four manufacturers, Tesla, Volvo, Audi, and Mercedes, have already met their voluntary commitment of 100 percent installation 3 years ahead of schedule. During the period September 1, 2018 through August 31, 2019, 12 of the 20 manufacturers equipped more than 75 percent of their new passenger vehicles with AEB, and overall manufacturers equipped more than 9.5 million new passenger vehicles with AEB.[1570]

Because of the NHTSA/IIHS agreement, the agencies assume that AEB will be in 100 percent of light vehicles by the 2023 MY. To derive installation rates for MYs 2018 through 2022, the agencies interpolate between the MY 2017 rate of 27 percent and the MY 2023 rate of 100 percent. To derive a MY 2015 estimate, the agencies modelled the results for MYs 2016-2023 and calculated a value for year x=0, essentially extending the model results back one year on the same trendline.

For FCW, the agencies used the same interpolation/modeling method as was used for AEB to derive an initial baseline trend. However, while both systems are available on some portion of the current MY fleet, the agencies anticipate that by MY 2023, all vehicles will have AEB systems that essentially encompass both FCW and AEB functions. The agencies therefore project a gradual increase in both systems until the sum of both systems penetration rates

[1568] Derived from Ward's Automotive Yearbooks, 2014 through 2018, % Factory Installed Electronic ADAS Equipment tables, weighting domestic and imported passenger cars and light trucks by sales volume.
[1569] https://www.nhtsa.gov/press-releases/nhtsa-iihs-announcement-aeb.
[1570] NHTSA Announces Update to Historic AEB Commitment by 20 Automakers. December 17, 2019. https://www.nhtsa.gov/press-releases/nhtsa-announces-update-historic-aeb-commitment-20-automakers

exceeds 100 percent. At that point, the agencies project a gradual decrease in FCW only installations until FCW only systems are completely replaced by AEB systems in MY 2023.

For LDW, Wards penetration data were available as far back as MY 2013, giving a total of 5 data points through MY 2017. The projection for LDW was derived by modelling these data points. The data indicate a near linear trend and our initial projections of future years were derived directly from this model. Wards did not report any of the more advanced LKA systems until MY 2016, leaving only 2 data points. The agencies modelled a simple trendline through these data points to estimate the pace of future LKA installations. As with Frontal crashes, the agencies assume a gradual phase-in of the most effective technology, LKA, will eventually replace the lesser technology, LDW, and the agencies allow gradual increases in both systems penetration until their sum exceeds 100 percent, at which point LDW penetration begins to decline to zero while LKA penetration climbs to 100 percent.

For blind spot crashes, Wards data was available for MYs 2013-2017 for BSD, but no data was available to distinguish LCA systems. LCA systems were available as optional equipment on at least 10 MY 2016 vehicles.[1571] In addition, Flannagan and Leslie found numerous cases in State data-bases involving vehicles with LCA. Because LCA data is not specifically identified, the agencies will estimate its frequency based on the samples found in Flannagan & Leslie. In that study, 62 percent of vehicles with blind spot technologies has BSD alone, while 38 percent had LCA (which includes BSD). The agencies employ this ratio to establish the relative frequency of these technologies in our projections. As with frontal and lane change technologies, the agencies assume a gradual phase-in of the most effective technology, LCA, will eventually replace the lesser technology, BSD, and the agencies allow gradual increases in both systems penetration until their sum exceeds 100 percent, at which point BSD penetration begins to decline to zero while LCA penetration climbs to 100 percent.

(iv) Impact Calculations

Table VI-168Table VI-168,

Table VI-169

Table VI-169, and

[1571] https://www.autobytel.com/car-buying-guides/features/10-cars-with-lane-change-assist-using-cameras-or-sensors-130847.

Table VI-170

Table VI-170 summarize the resulting estimates of impacts on fatality rates for frontal crash technologies, lane change technologies, and blind spot technologies respectively for MYs 2016-2035. All previously discussed inputs are shown in the tables. The effect of each technology is the product of its effectiveness, it's percent installation in the MY fleet, and the portion of the total light vehicle occupant target population that each technology might address. Since installation rates for each technology apply to different portions of the vehicle fleet (*i.e.*, vehicles have either the more basic or more advanced version of the technology), the effect of the two technologies combined is a simple sum of the two effects. Likewise, since each crash type addresses a unique target population, there is no overlap among the three crash types and the sum of the normalized crash impacts across all three crash types represents the total impact on fatality rates from these 6 technologies for each model year. These cumulative results are shown in the last column of

Table VI-170

Table VI-170. As technologies phase in to newer MY fleets[1572], their impact on the light vehicle occupant fatality rate increases proportionally to roughly 12 percent before levelling off. That is, eventually, by approximately MY 2026, these technologies are expected to reduce fatalities and fatality rates for new vehicles by roughly 12 percent below their initial baseline levels.

Table VI-168 - Phased Impact of Crashworthiness Technologies on Fatality Rates, Forward Collision Crashes

	Forward Collision Warning		Automatic Emergency Braking			
MY	FCW Eff	% Inst	AEB Eff	% Inst	% T.P.	Weighted Effectiveness
2015	8.0%	0.047	22.5%	0.011	4.0%	0.000243
2016	8.0%	0.176	22.5%	0.120	4.0%	0.001632
2017	8.0%	0.305	22.5%	0.270	4.0%	0.003383
2018	8.0%	0.421	22.5%	0.392	4.0%	0.004839
2019	8.0%	0.487	22.5%	0.513	4.0%	0.006136
2020	8.0%	0.365	22.5%	0.635	4.0%	0.006837
2021	8.0%	0.243	22.5%	0.757	4.0%	0.007538
2022	8.0%	0.122	22.5%	0.878	4.0%	0.008239
2023	8.0%	0	22.5%	1	4.0%	0.00894
2024	8.0%	0	22.5%	1	4.0%	0.00894
2025	8.0%	0	22.5%	1	4.0%	0.00894
2026	8.0%	0	22.5%	1	4.0%	0.00894
2027	8.0%	0	22.5%	1	4.0%	0.00894
2028	8.0%	0	22.5%	1	4.0%	0.00894
2029	8.0%	0	22.5%	1	4.0%	0.00894
2030	8.0%	0	22.5%	1	4.0%	0.00894
2031	8.0%	0	22.5%	1	4.0%	0.00894
2032	8.0%	0	22.5%	1	4.0%	0.00894
2033	8.0%	0	22.5%	1	4.0%	0.00894
2034	8.0%	0	22.5%	1	4.0%	0.00894
2035	8.0%	0	22.5%	1	4.0%	0.00894

[1572] While it is technically possible to retrofit these systems into the on-road fleet, such retrofits would be significantly more expensive than OEM installations. The agencies thus assume all on-road fleet penetration of these technologies will come through new vehicle sales.

Table VI-169 - Phased Impact of Crashworthiness Technologies on Fatality Rates, Lane Departure Crashes

	Lane Departure Warning		*Lane Keep Assist*			
						Weighted
MY	**LDW Eff**	**% Inst**	**LKA Eff**	**% Inst**	**% T.P.**	**Effectiveness**
2015	3.0%	0.177	30.0%	0.000	35.8%	0.001899
2016	3.0%	0.198	30.0%	0.088	35.8%	0.011565
2017	3.0%	0.280	30.0%	0.205	35.8%	0.024996
2018	3.0%	0.325	30.0%	0.323	35.8%	0.038101
2019	3.0%	0.379	30.0%	0.440	35.8%	0.051274
2020	3.0%	0.432	30.0%	0.558	35.8%	0.064447
2021	3.0%	0.325	30.0%	0.675	35.8%	0.075889
2022	3.0%	0.208	30.0%	0.792	35.8%	0.087224
2023	3.0%	0.090	30.0%	0.910	35.8%	0.098559
2024	3.0%	0	30.0%	1	35.8%	0.107278
2025	3.0%	0	30.0%	1	35.8%	0.107278
2026	3.0%	0	30.0%	1	35.8%	0.107278
2027	3.0%	0	30.0%	1	35.8%	0.107278
2028	3.0%	0	30.0%	1	35.8%	0.107278
2029	3.0%	0	30.0%	1	35.8%	0.107278
2030	3.0%	0	30.0%	1	35.8%	0.107278
2031	3.0%	0	30.0%	1	35.8%	0.107278
2032	3.0%	0	30.0%	1	35.8%	0.107278
2033	3.0%	0	30.0%	1	35.8%	0.107278
2034	3.0%	0	30.0%	1	35.8%	0.107278
2035	3.0%	0	30.0%	1	35.8%	0.107278

Table VI-170 - Phased Impact of Crashworthiness Technologies on Fatality Rates, Blind Spot Crashes and Combined Total – All Three Crash Types

	Blind Spot Detection		Lane Change Assist				
						Weighted	All 3 Tech Groups Combined
MY	BSD Eff	% Inst	LCA Eff	% Inst	% T.P.	Effectiveness	Avg Eff. Impact
2015	8.0%	0.206	32.0%	0.142	2.1%	0.00127	0.003412
2016	8.0%	0.311	32.0%	0.188	2.1%	0.001751	0.014948
2017	8.0%	0.389	32.0%	0.235	2.1%	0.002188	0.030567
2018	8.0%	0.454	32.0%	0.282	2.1%	0.002603	0.045543
2019	8.0%	0.528	32.0%	0.329	2.1%	0.003034	0.060444
2020	8.0%	0.603	32.0%	0.376	2.1%	0.003465	0.074749
2021	8.0%	0.577	32.0%	0.423	2.1%	0.003731	0.087159
2022	8.0%	0.530	32.0%	0.470	2.1%	0.003963	0.099426
2023	8.0%	0.483	32.0%	0.517	2.1%	0.004194	0.111693
2024	8.0%	0.436	32.0%	0.564	2.1%	0.004425	0.120643
2025	8.0%	0.390	32.0%	0.611	2.1%	0.004657	0.120875
2026	8.0%	0.343	32.0%	0.657	2.1%	0.004888	0.121106
2027	8.0%	0.296	32.0%	0.704	2.1%	0.00512	0.121338
2028	8.0%	0.249	32.0%	0.751	2.1%	0.005351	0.121569
2029	8.0%	0.202	32.0%	0.798	2.1%	0.005582	0.1218
2030	8.0%	0.155	32.0%	0.845	2.1%	0.005814	0.122032
2031	8.0%	0.108	32.0%	0.892	2.1%	0.006045	0.122263
2032	8.0%	0.061	32.0%	0.939	2.1%	0.006277	0.122495
2033	8.0%	0.014	32.0%	0.986	2.1%	0.006508	0.122726
2034	8.0%	0	32.0%	1	2.1%	0.006579	0.122797
2035	8.0%	0	32.0%	1	2.1%	0.006579	0.122797

(b) Fatality Trend Model

The revised fatality trend model differs from the model employed in the NPRM in four main respects:

- The fatality rates for individual model years and ages were re-calculated to reflect the revised VMT estimates, which in turn incorporate changes in both vehicle registration counts and the relationship between vehicle age and annual use;[1573]

[1573] These revised estimates of the number of miles traveled by vehicles of each model year during past calendar years were developed form the expanded sample of vehicles' odometer readings obtained by NHTSA, as described in [Insert Cross-cite].

- The revised model adds additional controls for changes to factors (such as driver demographics and behavior, and geographic patterns of travel) that can affect fatality rates for vehicles of all model years and ages;
- The revised analysis clusters past model years into "safety cohorts," which are groups of successive model years that exhibit similar fatality rates during their first years of use, in order to represent the actual historical pattern of safety improvements more realistically; and
- The model employs a slightly less complex mathematical relationship between a model year's age and its fatality rate (fatalities per mile driven), to describe the observed relationship more accurately.

Similar to the fatality trend model employed in the proposal, the revised estimates of annual travel were combined with tabulations of annual fatalities occurring among occupants of vehicles of each model year during past calendar years, performed using FARS data, to calculate historical fatality rates, measured as fatalities per billion miles traveled, by model year and calendar year. These data represent the dependent variable in the revised statistical model of fatality rates.

Longitudinal or time-series analyses such as the model of historical variation in fatality rates for individual model years need to incorporate three separate effects to account for all potential sources of variation. First, they need to employ model year in some form as an explanatory variable, to account for improvements in the safety of vehicles produced during successive model years that persist throughout their lifetimes in the vehicle fleet. This is an example of a "cohort effect" in the widely employed age-period-cohort form of analysis of population-wide behavior.[1574] Second, such a model must account for the effect of age on the safety of each individual model year as it grows older, accumulates mileage, and in most cases changes ownership one or more times during its expected service lifetime (the "aging effect" in age-period-cohort analysis).

Finally, most longitudinal analyses, including the historical safety model developed here, need to account explicitly for factors that vary over time—in this case, calendar years. By doing so, they can affect the safety of vehicles of all model years and ages making up the fleet during successive calendar years, or change the composition of total travel by vehicles of different model years and ages. In either case, such time-related factors—often referred to as "period effects" —can change the overall safety performance of the entire fleet from one calendar year to the next, *independently of and in addition to* the changes that would result from the combination of new model years entering the fleet while older ones are retired from service (the cohort effect), and the aging of all model years making up the fleet. For example, an increase in seat belt use among all drivers during a calendar year would be expected to reduce the fatality rates of vehicles of all model years and ages in use during that year, while an economic recession may change the composition of drivers and vehicles on the road during a calendar year. In either case, one result will be a change in the fleet-wide composite fatality rate for that calendar year.

[1574] For a detailed explanation of the rationale and methods for age-period-cohort analysis, *see* [REFERENCE].

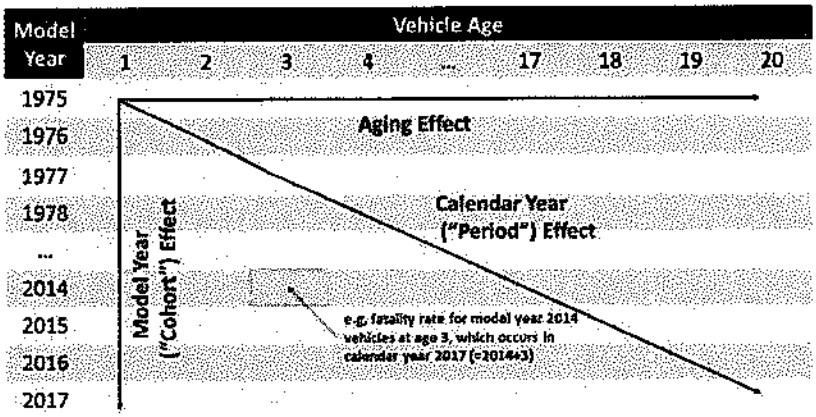

Figure VI-55

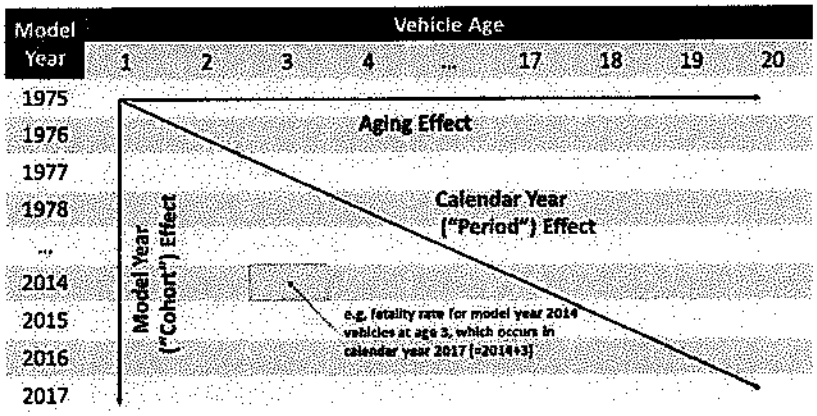

Figure VI-55 below illustrates the contributions of cohort, aging, and time-period effects to changes over time in population-wide behavior. As the figure indicates, these effects are conceptually independent, but interact in ways that combine to produce the observed historical

evolution of the fleet-wide fatality rate for light-duty vehicle occupants. Again, calendar year or time-period factors affect the safety performance of the entire fleet *independently of* the effect that would result from the combination of changes in the specific model years making up the fleet and the advancing ages of all model years, and their effect is *in addition to* those.

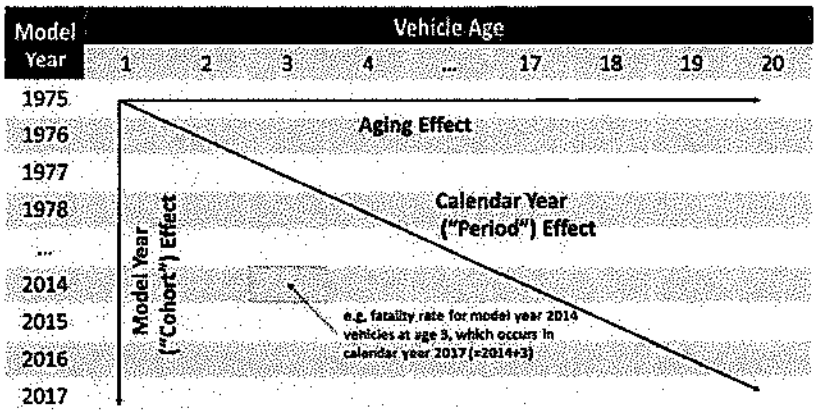

Figure VI-55 - Contributions of Cohort, Aging, and Time-Period Effects to Historical Changes in Fleet-Wide Fatality Rate

To introduce such period effects into the fatality trend model, which were absent from the NPRM analysis, the agencies obtained historical data on factors that varied by calendar year, and were expected to be responsible for such effects. As indicated previously, these included the following:

- Seat belt use, as measured by the fraction of drivers observed to be wearing lap and shoulder belts, estimated by NHTSA's National Occupant Protection Survey (NOPUS);
- Driving under the influence of alcohol or drugs, measured by the fraction of drivers reporting having recently done so in surveys conducted by the U.S. Centers for Disease Control (CDC);[1575]
- Use of hand-held electronic devices, measured by the fraction of drivers visually observed to be doing so in NHTSA's NOPUS;

[1575] The agencies also experimented with measures of drivers appearing to be under the influence of alcohol or drugs included in NHTSA's NOPUS.

- The fraction of licensed drivers who are male and under the age of 25 (historically the riskiest cohort of drivers), as reported by the FHWA's annual Highway Statistics publication;[1576]
- The fraction of miles traveled in rural areas, also as reported by FHWA;[1577] and
- The overall performance of the U.S. economy, as measured by the annual rate of unemployment.[1578]

The agencies were unable to obtain useful measures of roadway design parameters or road conditions that would be expected to affect safety. Although such measures exist, they tend to be reported for individual road and highway segments or routes, and it is difficult to combine these data into meaningful, aggregate measures that describe overall driving conditions that are likely to vary by calendar year. Nor could they identify satisfactory measures of incident response time or the effectiveness of emergency medical treatment in reducing the consequences of injuries occurring in motor vehicle crashes.

An important challenge to incorporating these time-period effects into the fatality trend model arose from the fact that their patterns of variation over the historical period the agencies analyzed (which extended from calendar year 1995 to 2017) were extremely closely correlated, making it virtually impossible to distinguish their independent contributions to improvements in fleet-wide safety over time. Table VI-171Table VI-171 below reports the pairwise correlation coefficients among the potential measures of period effects listed above. As it suggests, patterns of variation about their respective mean values over the period analyzed were very similar (with the exception of the unemployment rate), and the resulting high statistical correlations (or "collinearity") among them made it nearly impossible to identify their independent effects on variation in safety over time, even when controlling for the effects of model year and vehicle age.

[1576] Federal Highway Administration, Highway Statistics, various years, Table DL-20. https://www.fhwa.dot.gov/policyinformation/statistics.cfm.
[1577] Federal Highway Administration, Highway Statistics, various years, Table VM-1. https://www.fhwa.dot.gov/policyinformation/statistics.cfm.
[1578] Bureau of Labor Statistics, historical data series LNS14000000. https://data.bls.gov/cgi-bin/surveymost?ln.

Table VI-171 - Pairwise Correlation Coefficients Between Period Effect Variables

Variable	Unemployment Rate	% of VMT by Young Males	% of VMT in Rural Areas	% of Occupants Wearing Slap/Shoulder Belts	% of Young Drivers Using Hand-Held Electronic Devices	% of Drivers Consuming Alcohol
Unemployment Rate	1.00	-0.59	-0.54	0.54	0.40	-0.64
% of VMT by Young Males	-0.59	1.00	0.86	-0.98	-0.73	0.95
% of VMT in Rural Areas	-0.54	0.86	1.00	-0.86	-0.86	0.96
% of Occupants Wearing Lap/Shoulder Belts	0.54	-0.98	-0.86	1.00	0.73	-0.93
% of Young Drivers Using Hand-Held Electronic Devices	0.40	-0.73	-0.86	0.73	1.00	-0.80
% of Drivers Consuming Alcohol	-0.64	0.95	0.96	-0.93	-0.80	1.00

To address this difficulty, the agencies substituted a time trend—that is, a variable that takes the value of one in the first calendar year and increases by one in each successive calendar year—in an effort to capture the joint movements in the variables that were intended to measure time-period effects on safety. The agencies experimented with both linear and more complex time trends to capture the apparently declining rate of improvement in fleet-wide safety over time, but found that the linear trend captured the combined effects most reliably. Because the model's dependent variable is the natural logarithm of model year and age-specific fatality rates, using a linear time trend corresponds to assuming a constant *percentage* decline in fatality rates each year (rather than a constant absolute decline each year), and this pattern appeared to provide the best fit to the observed historical pattern of safety improvements. Finally, after noting that the linear time trend did not fully capture the effects on fleet-wide safety associated with the economic recessions in 2001 and 2007-11, the agencies supplemented the time trend with indicator (or "dummy") variables for these years, finding that only those for 2008, 2009, and 2010 improved its explanatory power significantly.

Another significant improvement to the NPRM analysis was to group model years into "safety cohorts" on the basis of similarity in their fatality rates when new (that is, during their first year in service), rather than treating each model year as a separate cohort. Groupings were created through a combination of identifying years when new safety regulations initially took effect or were phased in, examining of first-year fatality rates, and limited statistical experimentation. Grouping successive model years reduces the number of cohorts significantly, since similar fatality rates were typically observed for at least five, and sometimes as many as ten, consecutive model years over the historical period the agencies examined. Grouping model years into a smaller number of cohorts rather than treating each model year as a separate cohort has offers the advantage of introducing some variation in the ages of vehicles making up the same cohort during a calendar year, which improves the statistical reliability with which the

independent effect of age itself can be estimated.

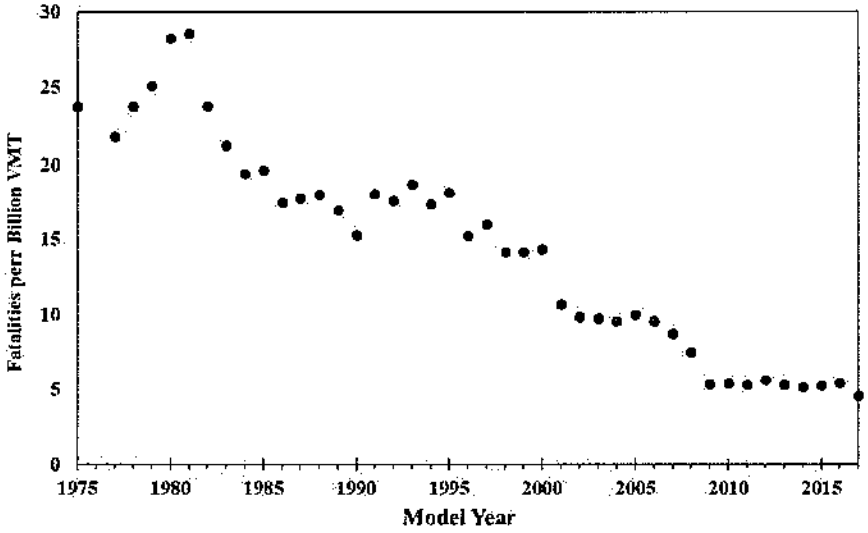

Figure VI-56

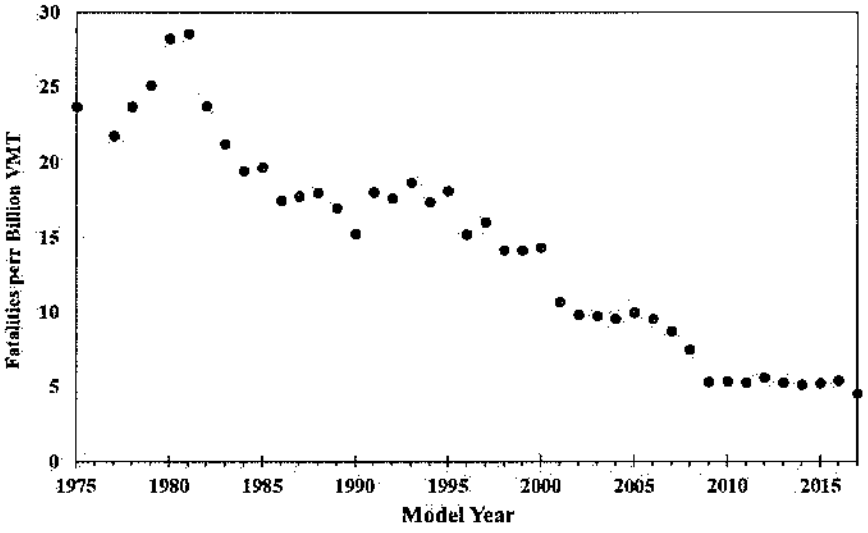

Figure VI-56 below shows historical variation in the fatality rates of past model years when each one was newly-introduced (*i.e.*, during its first year in use).[1579] It clearly displays the significant improvement in the safety of new vehicles over time in response to improvements in safety features, including those required by NHTSA's safety regulations. The figure also clearly documents the natural clustering of fatality rates for successive model years that was used to identify and define the safety cohorts used in the revised model. In the panel structure of the model, which combines time-series and cross-section variation in fatality rates for individual model years as their ages vary across calendar years, the clustering of first-year fatality rates for successive model years is captured by using separate "fixed effects" for each safety cohorts illustrated in the figure. Some judgment is inevitably required to distinguish between successive cohorts and identify when the fatality rate for new model years has changed significantly; the agencies experimented with using from five to eight cohorts, ultimately finding that the agencies could distinguish most reliably among the fatality rates for five cohorts.

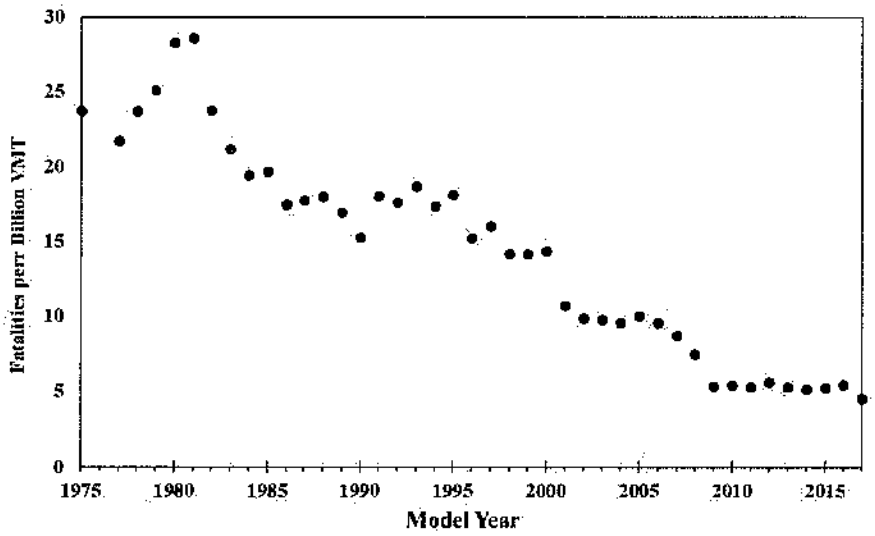

Figure VI-56 - Fatality Rates for New Light-Duty Vehicles by Model Year

A final revision to the NPRM model was to employ a slightly less complex mathematical relationship between a model year's age and its fatality rate than had been used in the NPRM version. A slightly simpler relationship proved adequate to capture fully the complex—but

[1579] For simplicity, the figure assumes that each model year's first year of use was the calendar year identical to its designated model year; for example, the first full year of use for model year 2000 was assumed to be calendar year 2000. In fact, new vehicles frequently become available for purchase during the calendar year preceding their designated model year and continue to be sold through the calendar year following it, although most sales occur during the calendar year matching their designated model year.

strongly recurring—pattern of fatality rates for past model years as they aged. Specifically, fatality rates have tended to remain approximately constant for the first few years of most recent model years' lifetimes, before increasing steadily through age 15-20 and then declining gradually over the remainder of their lifetimes, as progressively fewer of their original number remain in use.

As discussed previously, the increase in fatality rates through approximately age 20 is generally thought to result primarily from the fact that used vehicles are commonly purchased and driven by members of households whose demographic characteristics, driving behavior, and geographic locations are associated with more frequent or severe crashes. Of course, increased frequency of mechanical failures as vehicles age and accumulate mileage also seems likely to contribute to this pattern. In contrast, the consistent tendency for fatality rates to decline after about age 20 is less well understood, but may owe partly to the demographic characteristics and driving behavior of owners of very old vehicles. Whatever its source, the number of vehicles remaining in service past age 20 is so small and their use typically so limited that their contribution to the fleet-wide fatality rate is minimal.

Figure VI-57

Figure VI-57 documents the relationship between age and fatality rate for selected past model years.[1580] As it shows, fatality rates for recent model years follow a complex but strikingly similar pattern of increase and subsequent decline with increasing age, although the figure also shows that the earliest model years included in the sample (1975-1980) tended not to display increasing fatality rates in the first half of their lifetimes. At the same time, the figure illustrates the gradual downward shift in fatality rates at all ages for successive past model years, although there is considerable variation in the extent of this shift for individual model years, particularly when they are examined at specific ages. That is, the downward shift in fatality rates for successive model years is not necessarily "monotonic," particularly when it is examined at specific individual ages.

[1580] Without the use of colors to distinguish model years, the figure is difficult to interpret when all model years are included.

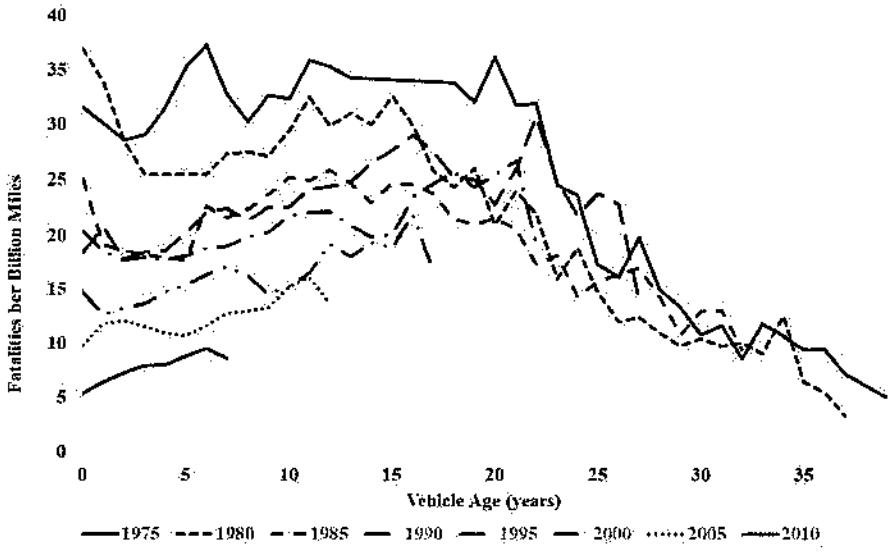

Figure VI-57 - Fatality Rate for Light-Duty Vehicle Occupants by Age for Selected Model Years

Based on examination of the information summarized in

Figure VI-57

Figure VI-57, the agencies conclude that the effect of increasing age on vehicle safety appears to be largely independent of the improvement in new cars' fatality rates over successive model years, and appears to operate similarly for all except the earliest model years in our historical sample (which includes model years 1975-2017).[1581] As a formal statistical test, the agencies experimented with allowing the aging effect to change across model years when the agencies estimated the revised model, anticipating that newer safety technologies and vehicle designs might "flatten" the relationship between fatality rates and age—that is, reduce the degree

[1581] Of course, the agencies cannot observe the safety performance of all model years included in the agencies' data sample over their entire lifetimes, because the data the agencies use to estimate the model start in calendar year 1990, by which time all model years before 1990 were no longer new–for example, MY1975 cars are already 15 years old by then–while the newest model years in the agencies' sample are still very "young" when the agencies' data ends in calendar year 2017. Thus, the agencies have only incomplete information about the relationship of fatality rates to age over the entire lifetimes of these model years, so it is possible that this relationship differs at particularly early or advanced ages for the oldest and newest model years in the agencies' sample.

to which fatality rates increased over the 5-20 year range of vehicle ages—for newer model years.

> However, the agencies found no evidence that the effect of age on safety changed significantly for more recent model years compared to older ones, so the agencies retained the assumption of identical aging effects for all model years in the revised model.[1582] Thus the revised model shows progressively lower fatality rates for more recent model years when they are new, but fatality rates for all model years increase with age according to the same non-linear pattern displayed in

Figure VI-57

Figure VI-57. On a related question, the agencies also found that including the squared and cubed values of age in addition to age itself as explanatory variables in the model (but excluding the fourth power of age, which had been included in the NPRM model) proved adequate to capture the pattern of variation in fatality rates with increasing age that most past model years have exhibited.[1583] Table I-11 below reports the estimated parameter values for alternative specifications of the model, together with various goodness-of-fit and other diagnostic measures. The analysis described in the following section uses the estimated time trend from Model 3 in the table, which implies annual reduction in fatality rates for all model years of 3.34 percent.

[1582] Specifically, the agencies tested for interactions between the age and model year variables, which would reveal changes in the relationship between fatality rates and age for more recent model years, but found that such interaction effects were generally not statistically significant. Allowing for interactions between age and the indicator variables for safety cohorts (recall that these represent groupings of successive model years) produced this same result—few of the interaction effects were statistically significant.

[1583] An analysis of alternative specifications analyzed by the agencies can be found in the FRIA at [Insert Page Number].

Table I-11- Estimation Results for Alternative Specifications of Fatality Rate Trend Model

Variable	Estimated Coefficient in Model Specification (standard errors in parentheses) *** p<0.01, ** p<0.05, * p<0.1					
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Model Years 1975-82	1.732*** (0.060)	1.624*** (0.066)	2.272*** (0.067)	1.665*** (0.063)	1.555*** (0.069)	2.318*** (0.073)
Model Years 1983-89	0.467*** (0.027)	0.486*** (0.033)	0.224*** (0.031)			
Model Years 1990-97	0.855*** (0.032)	0.896*** (0.053)	0.461*** (0.050)			
Model Years 1998-2007	0.893*** (0.046)	0.954*** (0.080)	0.357*** (0.074)			
Model Years 2008-17	0.815*** (0.072)	0.897*** (0.113)	0.170* (0.101)			
Model Years 1983-87				0.377*** (0.027)	0.453*** (0.034)	0.188*** (0.032)
Model Years 1988-89				0.718*** (0.038)	0.840*** (0.049)	0.447*** (0.048)
Model Years 1990-97				0.874*** (0.031)	1.064*** (0.058)	0.535*** (0.058)
Model Years 1998-2000				0.916*** (0.046)	1.175*** (0.082)	0.492*** (0.080)
Model Years 2001-06				0.939*** (0.051)	1.254*** (0.096)	0.459*** (0.094)
Model Years 2007-08				0.895*** (0.073)	1.264*** (0.120)	0.374*** (0.114)
Model Years 2009-17				0.868*** (0.075)	1.274*** (0.129)	0.298** (0.123)
Vehicle Age	0.475*** (0.023)	0.434*** (0.049)	-0.823*** (0.081)	0.496*** (0.023)	0.332*** (0.049)	-0.790*** (0.078)
Vehicle Age^2		0.0163 (0.017)	0.866*** (0.049)		0.0714*** (0.019)	0.834*** (0.048)
Vehicle Age^3			-0.167*** (0.009)			-0.157*** (0.009)
Calendar Year 2007	-0.037 (0.041)	-0.0372 (0.041)	-0.0426 (0.034)	-0.0365 (0.039)	-0.0391 (0.039)	-0.0407 (0.033)
Calendar Year 2008	-0.0538 (0.040)	-0.0543 (0.041)	-0.0574* (0.033)	-0.0542 (0.039)	-0.0569 (0.038)	-0.0580* (0.032)
Calendar Year 2009	-0.188*** (0.040)	-0.189*** (0.040)	-0.190*** (0.033)	-0.189*** (0.038)	-0.192*** (0.038)	-0.191*** (0.032)
Calendar Year 2010	-0.120*** (0.040)	-0.121*** (0.040)	-0.121*** (0.033)	-0.121*** (0.038)	-0.125*** (0.037)	-0.121*** (0.031)
Calendar Year 2011	-0.0387 (0.039)	-0.0394 (0.039)	-0.0375 (0.032)	-0.039 (0.037)	-0.0428 (0.037)	-0.0383 (0.031)
Time Trend (1975=1, 1976=2,...)	-0.0561*** (0.002)	-0.0586*** (0.003)	-0.0334*** (0.003)	-0.0577*** (0.002)	-0.0698*** (0.004)	-0.0376*** (0.004)
No. of Observations	705	705	705	705	705	705
R-squared within (1)	0.5036	0.5043	0.6621	0.5164	0.5266	0.6658
R-squared between (2)	0.5743	0.5627	0.8081	0.6375	0.5999	0.7942
R-squared overall (3)	0.3189	0.3031	0.6447	0.3163	0.2583	0.5902
corr(u_i, Xb) (4)	-0.6649	-0.6987	-0.0755	-0.6787	-0.7986	-0.2457
sigma_u (5)	0.3790	0.4071	0.1772	0.3370	0.4648	0.1803
sigma_e (6)	0.2281	0.2281	0.1884	0.2167	0.2146	0.1804
rho (7)	0.7342	0.7611	0.4693	0.7076	0.8243	0.4997

(1) Indicates proportion of variance among individual model year cohorts model accounts for;
(2) Indicates proportion of variance for all model year cohorts over time model accounts for.
(3) Indicates proportion of total variance among individual model year cohorts and over time model accounts for,
(4) Correlation between model error term and explanatory variables included in model.
(5) Standard deviation of residual terms for individual model year cohorts across time periods.
(6) Standard deviation of overall model error term.
(7) Proportion of total variance accounted for by differences among model year cohorts.

(c) Using the Model and Technology Analysis to Forecast Fatality Rates

The newest safety cohort includes model years from 2009 to 2017, so in effect the agencies estimate that all those model years have essentially the same fatality rate in their first year of use. The agencies apply the estimated effectiveness of crash avoidance technologies in reducing fatal crashes to the observed fatality rate for model years 2009 to 2017 vehicles during their first year in use to estimate fatality rates for future model years during the first year each one is introduced. Figure VI-58Figure VI-58 below shows the result of this process; as it indicates, fatality rates for new model years decline gradually through 2035 and then stabilize, reflecting the fact that the agencies are only able to project the effectiveness of emerging crash avoidance technologies on the safety of new vehicles through that year.

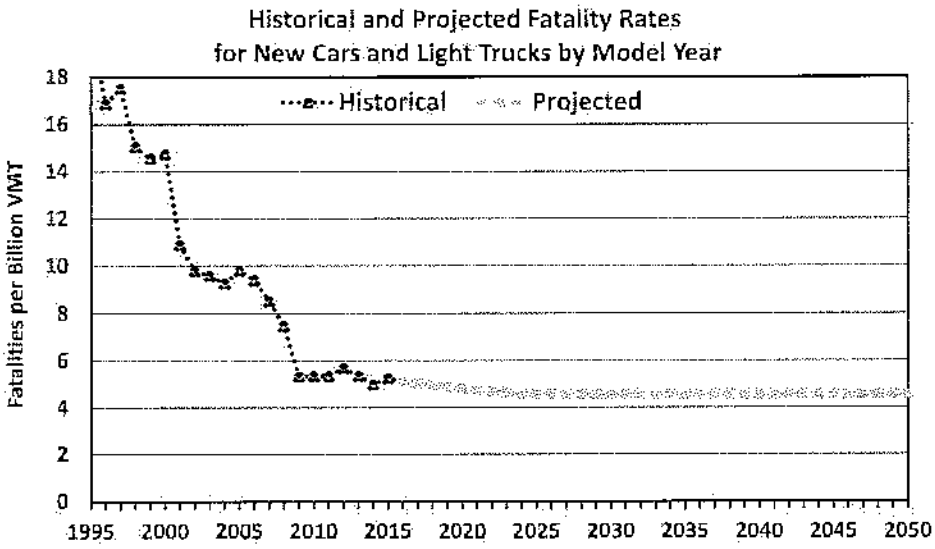

Figure VI-58 - Fatality Rates for New Cars and Light Trucks by Model Year

The next step in constructing the forecast of fleet-wide fatality rates is to apply the age-related increases in the fatality rate for each model year making up the previous calendar year's fleet. For example, the agencies assume that the fatality rates for all model years comprising the light-duty vehicle fleet in 2017 increase with age according to the relationship captured by the estimated coefficients on the age variables in the preferred model specification shown in Table BB. The same assumption is applied to all new model years introduced in subsequent years.

Finally, the agencies also assume that the historical decline in fatality rates observed over past calendar years (the "period effect" captured by the time trend variable) will continue into the future. This implies that fatality rates for all model years and ages will decline by an additional 3.34 percent in each successive future calendar year from the rates that would have resulted from the combined effects of continuing improvements in the safety of newly-introduced model years and the effect of increasing age.[1584]

This process produces an estimate of the fatality rate for each model year making up the fleet during each future calendar year. That estimate reflects the combination of (1) reductions in fatality rates for new cars, reflecting the continued improvements in their safety due to crash avoidance technologies (through MY2035); (2) increases in the fatality rates for each model year in the fleet from the previous calendar year, which represent the effect of age estimated by the historical model; and (3) the continuing downward trend in fatality rates for all vehicles except the newest model year in each calendar year's fleet, which is derived from the historical model. The agencies then weight the fatality rate for each model year making up a future year's fleet by the fraction of VMT it accounts for, and sum the results to produce our estimate of the fleet-wide fatality rate. The CAFE model does not actually use this fleet-wide fatality rate, because all of the fatality calculations are performed separately for each individual model year making up the fleet, which are then aggregated; nevertheless, the agencies provide the fleet-wide rate as a useful check on the reasonableness of our fatality rate forecasts for individual model years as they enter the fleet and age over their respective lifetimes.

[1584] The agencies do not apply this trend reduction to the fatality rates for the newest model year in each calendar year's fleet, because it is assumed to be independent of both the decline in new-car fatality rates and the aging effect.

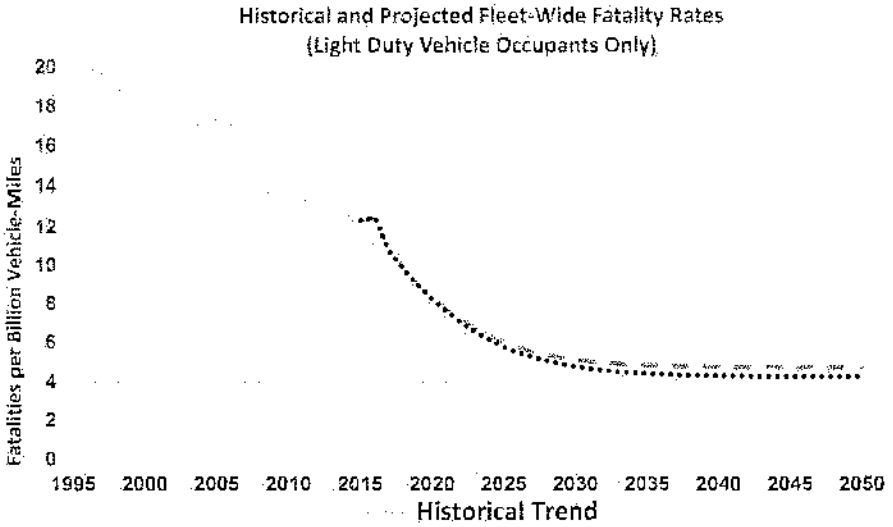

Figure VI-59 – Historical and Projected Fleet-Wide Fatality Rates

(d) Impact of Advanced Technologies on Older Vehicle Fatality Rates

In the NPRM, the agencies calculated the potential safety impacts of delayed purchases of vehicles with new safety technology that might result from higher vehicles prices associated with more stringent CAFE standards. A number of commenters noted that since these improvements will be driven by crash avoidance technologies, they will also benefit older vehicles and reduce their fatality rates as well. For example, CARB noted that "safety improvements generally provide systematic safety benefits to all vehicles in the on-road fleet, not only to new vehicles. However, NHTSA's safety model assigns safety coefficients to vehicles solely based on their model year and it fails to incorporate the effect that new safety designs and technologies will have on systematically improving fleet-wide on-road safety." IPI similarly noted that should "new safety technologies be adopted, the predicted fatalities for all the older vehicle vintages will have to be lowered as well because effective crash avoidance technologies will lower all vehicles' fatality costs."

The agencies agree that the users of older vehicles will also benefit from crash avoidance technologies on newer vehicles. In response, the agencies have modified our methodology to reflect lower fatality rates on older vehicles resulting from the new crash avoidance technologies. Crash avoidance technologies prevent crashes from happening and thus benefit both the vehicle with the technology and any other vehicles that it might have collided with. However, the scope of these impacts on older vehicle's fatality rates are somewhat limited due to several factors:

- Single vehicle crashes, which make up about half of all fatal crashes, will not be affected. Only multi-vehicle crashes involving a newer vehicle with the advanced technology and an older vehicle will be affected. Multi-vehicle crashes account for roughly half of all light vehicle occupant fatalities.
- For a new safety technology to benefit an older vehicle in a multi-vehicle crash, the vehicle with the technology must have been in a position to control, or prevent the crash. For example, in front-to-rear crashes which can be addressed by FCW and AEB, the older vehicle would only benefit if it was the vehicle struck from behind. If the struck vehicle were the newer vehicle, its AEB technology would not prevent the crash. Logically this would occur in roughly half of two-vehicle crashes and a third of all three-vehicle crashes. Since most multi-vehicle crashes involve only two vehicles, roughly half of all multi-vehicle crashes might qualify.
- The benefits experienced by older vehicles are proportional to the probability that the vehicles they collide with are newer vehicles with advanced crash avoidance technology. The agencies estimate that the probability that this would occur is a function of the relative exposure of vehicles by age, measured by the portion of total VMT driven by vehicles of that age. Based on VMT schedules (*see* CY 2016 example in Table VI-172Table VI-172), new (current MY) vehicles account for about 9.6 percent of annual fleet VMT. The relevant portion would increase over time as additional MY vehicles are produced with advanced technologies. However, the portion of older vehicle crashes that might be affected by newer technologies is initially very small—only about 2 percent (.5*.5*.096) of older vehicles involved in crashes might benefit from advanced crash avoidance technologies in other vehicles in the first year.

Table VI-172 - Registrations, Total VMT, and Proportions of Total VMT by Vehicle Age

REGISTRATIONS, TOTAL VMT, AND PROPORTIONS OF TOTAL VMT BY VEHICLE AGE				
		CY 2016		
Model Year	Age	Registrations	kVMT	% Total VMT
1977	39	286,019	927,877	0.000329
1978	38	332,760	1,247,190	0.000443
1979	37	375,561	1,556,553	0.000553
1980	36	205,942	903,948	0.000321
1981	35	208,192	1,010,499	0.000359
1982	34	213,697	1,130,039	0.000401
1983	33	265,583	1,496,439	0.000531
1984	32	408,058	2,428,835	0.000862
1985	31	477,178	2,993,451	0.001063
1986	30	605,932	3,991,280	0.001417
1987	29	644,568	4,396,414	0.001561
1988	28	629,179	4,431,880	0.001574
1989	27	747,740	5,475,868	0.001944

1990	26	755,244	5,685,511	0.002019
1991	25	899,252	6,991,287	0.002483
1992	24	1,005,716	8,055,442	0.00286
1993	23	1,308,396	10,784,619	0.003829
1994	22	1,738,409	14,739,099	0.005234
1995	21	2,212,145	19,191,169	0.006815
1996	20	2,364,368	21,059,984	0.007478
1997	19	3,401,992	31,134,256	0.011055
1998	18	4,079,728	38,358,375	0.013621
1999	17	5,377,629	52,039,074	0.018478
2000	16	6,826,267	67,907,099	0.024113
2001	15	7,475,530	76,512,692	0.027169
2002	14	8,912,404	94,016,400	0.033384
2003	13	9,825,521	106,764,943	0.037911
2004	12	10,806,847	121,080,704	0.042994
2005	11	11,649,021	134,404,144	0.047725
2006	10	11,699,430	138,962,811	0.049344
2007	9	12,519,932	153,300,527	0.054435
2008	8	11,781,605	148,871,424	0.052862
2009	7	8,171,782	106,120,610	0.037682
2010	6	9,944,848	133,696,015	0.047474
2011	5	10,967,994	152,795,831	0.054256
2012	4	12,409,627	177,760,326	0.06312
2013	3	14,197,792	210,386,962	0.074706
2014	2	14,726,690	226,423,858	0.0804
2015	1	16,208,153	257,415,893	0.091405
2016	0	16,338,755	269,760,666	0.095789
Total		223,005,486	2,816,209,994	1

To reflect this safety benefit for older vehicles, the agencies calculated a revised fatality rate for each older MY vehicle on the road based on its interaction with each new MY starting with MY 2021 vehicles based on the following relationship:

Revised fatality rate = Fm-((x-y)mnp)+F(1-m)

Where: F = initial fatality rate for each MY

x = baseline MY fatality rate

y = current MY fatality rate

m = proportion of occupant fatalities that occur in multi-vehicle crashes (52 percent)

n = probability that crash is with a new MY vehicle containing advanced technologies

p = probability that new vehicle is "striking" vehicle

The initial fatality rate for each vehicle MY (F) was derived by combining fatality counts from NHTSA's Fatality Analysis Reporting System (FARS) with VMT data from IHS/Polk.

The baseline MY fatality rate (x) represents the baseline rate over which the impact of new crash avoidance technologies should be measured It establishes the baseline rate for each MY that will be compared to the most current MY rate to determine the change in fatality rate (FR) for each MY. The relative effectiveness of new crash-avoidance technologies in modifying the fatality rate of older model vehicles is measured differently depending on the age of the older vehicle. The fatality rate is a historical measure that reflects safety differences due to both crashworthiness technologies such as air bags and crash avoidance technologies such as electronic stability control, but up through MY 2017, crashworthiness standards are the predominate cause of these differences. The most recent significant crashworthiness safety standard, which upgraded roof strength standards which was effective in all new passenger vehicles in MY 2017. Crashworthiness standards would not have secondary benefits for older MY vehicles.. Post MY 2017, the agencies believe crash avoidance technologies will drive safety improvements.. To isolate the added crash avoidance safety expected in newer vehicles, the marginal impact of the difference between the MY 2017 fatality rate and the most current MY fatality rate represents the added marginal effectiveness of new crash-avoidance technologies of each subsequent MY for MYs 2017 and earlier. Beginning with MY 2018, the difference between the older MY fatality rate and most current MY rate determines the potential safety benefit for the older vehicles.

The current MY fatality rate (y), represents the projected fatality rate of future MY vehicles after adjustment for the impacts of the advanced crash avoidance technologies and projected improvements in non-technology factors examined in this analysis. This process was discussed in detail in the previous section.

The proportion of passenger vehicle occupant fatalities that occur in multi-vehicle crashes (m), was derived from an analysis of occupants of fatal passenger vehicle crashes from 2002-2017 FARS. The analysis indicated that 47.8 percent of fatal crash occupants were in single vehicle crashes, 40.2 percent were in two vehicle crashes, and 12 percent were in crashes involving 3 or more vehicles. Overall, 52.2 percent were in multi-vehicle crashes.

The portion of older vehicle crashes involving newer vehicles containing advanced crash avoidance technologies (n), is assumed to be equal to the cumulative risk exposure of vehicles that have these technologies. This exposure is measured by the product of annual VMT by vehicle age and registrations of vehicles of that age. The Volpe model calculates this dynamically, but as an example, based on 2016 registration data (*see* Table VI-172Table VI-172 above), the most current MY would represent 9.6 percent of all VMT in a calendar year, implying a 9.6 percent probability that the vehicle encountered would be from the most current MY. This percentage would increase for each CY as more MY vehicles adopt advanced crashworthiness technologies. The agencies note that other factors such as uneven

concentrations of newer vs. older vehicles or improved crash avoidance in the younger vehicles already on the road that are the basis for the agencies' VMT proportion table might disrupt this assumption, but it is likely that this would only serve to slow the probability of these encounters, making this a conservative assumption in that it maximizes the probability that older vehicles might benefit from newer technologies.

The probability that the vehicle with advanced crash avoidance technology is the controlling or striking vehicle (p), was calculated using the relative frequency of fatal crash occupants in multi-vehicle crashes. As noted previously, 40.2 percent were in two vehicle crashes, and 12 percent were in crashes involving 3 or more vehicles. The agencies assume a probability of 50 percent for two vehicle crashes and 33 percent for crashes with 3 or more vehicles. Weighted together the agencies estimate a 46.1 percent probability that, given a multi-vehicle crash involving a vehicle with advanced technologies and an older vehicle without them, the newer vehicle will be the striking vehicle or in a position where its crash avoidance technologies might influence the outcome of the crash with the older vehicle.

This process is illustrated in Table VI-173Table VI-173 below for adjustments due to improvements in MY 2021 vehicles back through MY 1995. In Table VI-173Table VI-173, the actual model year fatality rate is shown in the second column. As noted above, the base fatality rate, shown in column 3, is the MY 2017 rate for all MYs prior to 2018, after which it becomes the actual MY rate. Column 4 shows the difference between the fatality rate for MY 2021 and the base rate for each MY. Column 5 shows the resulting revised fatality rate that would be used for each older MY, and column 6 and 7 list the change in that rate. The various factors noted in the above formula are applied in column 5. The results indicate a 0.006 decrease in pre-2018 MY vehicles fatality rates, with declining impacts going forward to MY 2021. In subsequent years, this impact would grow to reflect the both the increased probability that an older vehicle would crash with vehicles containing advanced technology, as well as the increased technology levels in progressively newer vehicles. This table was created using NPRM inputs and is provided for explanatory purposes only. The actual impacts are dynamically calculated within the Volpe model and reflect revised fatality rate trends going forward and cover even older model years.

Table VI-173 - Adjustment to Fatality Rates of Older Vehicles to Reflect Impact of Advanced Crash Avoidance Technologies in Newer Vehicles

Model Year	MY Fatality Rate	Base Fatality Rate	Difference Base FR - New MY FR	Revised Fatality Rate	% Change	Difference
1995	17.979	8.628	0.269	17.973	0.00034	-0.0062
1996	16.519	8.628	0.269	16.513	0.00038	-0.0062
1997	15.789	8.628	0.269	15.783	0.00039	-0.0062
1998	14.709	8.628	0.269	14.703	0.00042	-0.0062
1999	13.679	8.628	0.269	13.673	0.00045	-0.0062
2000	12.909	8.628	0.269	12.903	0.00048	-0.0062
2001	12.259	8.628	0.269	12.253	0.00051	-0.0062

2002	11.489	8.628	0.269	11.483	0.00054	-0.0062
2003	10.889	8.628	0.269	10.883	0.00057	-0.0062
2004	10.349	8.628	0.269	10.343	0.00060	-0.0062
2005	9.679	8.628	0.269	9.673	0.00064	-0.0062
2006	9.349	8.628	0.269	9.343	0.00066	-0.0062
2007	9.284	8.628	0.269	9.278	0.00067	-0.0062
2008	9.220	8.628	0.269	9.214	0.00067	-0.0062
2009	9.155	8.628	0.269	9.149	0.00068	-0.0062
2010	9.090	8.628	0.269	9.084	0.00068	-0.0062
2011	9.024	8.628	0.269	9.018	0.00069	-0.0062
2012	8.959	8.628	0.269	8.953	0.00069	-0.0062
2013	8.893	8.628	0.269	8.887	0.00070	-0.0062
2014	8.827	8.628	0.269	8.821	0.00070	-0.0062
2015	8.761	8.628	0.269	8.755	0.00071	-0.0062
2016	8.694	8.628	0.269	8.688	0.00071	-0.0062
2017	8.628	8.628	0.269	8.622	0.00072	-0.0062
2018	8.561	8.561	0.202	8.556	0.00054	-0.00466
2019	8.494	8.494	0.135	8.491	0.00037	-0.00311
2020	8.426	8.426	0.068	8.425	0.00018	-0.00156
2021	8.359	8.359	0.000	8.359	0	0

(e) Dynamic Fleet Composition

As described in the dynamic fleet share discussion in Chapter XX, vehicle prices influence the distribution of cars and trucks purchased.[1585] As light trucks, SUVs and passenger cars have different fatality rates, fleets with different compositions of vehicles will have varying amounts of fatalities. Since mass-safety fatalities are calculated by multiplying mass point-estimates by VMT, which implicitly captures the impact of the dynamic fleet share model, the estimates of mass-safety fatalities in the previous section include the impact of vehicle prices on fleet composition.

c) Summary of Safety Impacts

[Text Forthcoming]

[1585] As regulatory compliance costs increase vehicle prices, consumers' preferences shift towards smaller, cheaper vehicles. As explained in more detail in Chapter XX, this does not necessarily mean that the proportion of SUVs to sedans decreases when prices are high, but rather the saturation of larger vehicles in the fleet slows.

Table I-174[Text Forthcoming]

Table I-174 through Table I-177Table I-177 summarize the safety effects of CAFE standards across the various alternatives under the 3% and 7% discount rates. Table I-178Table I-178 through

	Alternative						
	1	2	3	4	5	6	7
Model Years	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities							
Mass Changes	-18	-17	-17	-17	-14	-15	-14
Scrappage/Sales Impacts	-546	-512	-455	-427	-344	-358	-300
Subtotal	***-564***	***-529***	***-471***	***-444***	***-359***	***-373***	***-314***
Rebound Effect	-3332	-3224	-2694	-2567	-1884	-1887	-1342
Total	***-3896***	***-3754***	***-3166***	***-3010***	***-2243***	***-2260***	***-1656***
Fatality Costs ($b)							
Mass Changes	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Scrappage/Sales Impacts	-4.3	-4.0	-3.6	-3.4	-2.7	-2.9	-2.3
Subtotal	***-4.4***	***-4.1***	***-3.7***	***-3.5***	***-2.8***	***-3.0***	***-2.4***
Rebound Effect	-23.5	-22.7	-19.1	-18.2	-13.3	-13.4	-9.6
Total	***-27.9***	***-26.9***	***-22.8***	***-21.7***	***-16.1***	***-16.4***	***-12.0***
Non Fatal Crash Costs ($b)							
Mass Changes	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Scrappage/Sales Impacts	-7.1	-6.7	-6.0	-5.6	-4.5	-4.7	-3.8
Subtotal	***-7.3***	***-6.9***	***-6.2***	***-5.8***	***-4.6***	***-4.9***	***-4.0***
Rebound Effect	-38.7	-37.5	-31.4	-29.9	-21.9	-22.2	-15.8
Total	**-46.0**	**-44.3**	**-37.6**	**-35.7**	**-26.6**	**-27.1**	**-19.8**

Table I-181

	Alternative						
	1	2	3	4	5	6	7
Model Years	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities							

Mass Changes	-18	-17	-17	-17	-14	-15	-14
Scrappage/Sales Impacts	-546	-512	-455	-427	-344	-358	-300
Subtotal	***-564***	***-529***	***-471***	***-444***	***-359***	***-373***	***-314***
Rebound Effect	-3332	-3224	-2694	-2567	-1884	-1887	-1342
Total	***-3896***	***-3754***	***-3166***	***-3010***	***-2243***	***-2260***	***-1656***
Fatality Costs ($b)							
Mass Changes	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Scrappage/Sales Impacts	-4.3	-4.0	-3.6	-3.4	-2.7	-2.9	-2.3
Subtotal	***-4.4***	***-4.1***	***-3.7***	***-3.5***	***-2.8***	***-3.0***	***-2.4***
Rebound Effect	-23.5	-22.7	-19.1	-18.2	-13.3	-13.4	-9.6
Total	***-27.9***	***-26.9***	***-22.8***	***-21.7***	***-16.1***	***-16.4***	***-12.0***
Non Fatal Crash Costs ($b)							
Mass Changes	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Scrappage/Sales Impacts	-7.1	-6.7	-6.0	-5.6	-4.5	-4.7	-3.8
Subtotal	***-7.3***	***-6.9***	***-6.2***	***-5.8***	***-4.6***	***-4.9***	***-4.0***
Rebound Effect	-38.7	-37.5	-31.4	-29.9	-21.9	-22.2	-15.8
Total	**-46.0**	**-44.3**	**-37.6**	**-35.7**	**-26.6**	**-27.1**	**-19.8**

Table I-181**Error! Reference source not found.** summarize these impacts for CO_2 standards. As noted in Section [Text Forthcoming] societal impacts are valued using a $10.4 million value per statistical life (VSL). Note that fatalities in these tables are undiscounted – only the monetized societal impact is discounted.

[Text Forthcoming]

Table I-174 - Change in Safety Parameters from Augural CAFE Standards Baseline
Average Annual Fatalities, CY 2036-2045, 3% Discount Rate

	Alternative						
	1	2	3	4	5	6	7
Model Years	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities							
Mass Changes	-3	-3	-3	-3	-2	-2	-1
Scrappage/Sales Impacts	-12	-13	-17	-18	-17	-13	-9
Subtotal	***-16***	***-16***	***-20***	***-21***	***-19***	***-15***	***-11***
Rebound Effect	-333	-327	-280	-265	-201	-172	-123
Total	***-349***	***-343***	***-300***	***-286***	***-220***	***-187***	***-133***
Fatality Costs ($b)							
Mass Changes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrappage/Sales Impacts	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Subtotal	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***
Rebound Effect	-1.8	-1.8	-1.6	-1.5	-1.1	-1.0	-0.7
Total	***-1.9***	***-1.9***	***-1.7***	***-1.6***	***-1.2***	***-1.0***	***-0.7***
Non Fatal Crash Costs ($b)							
Mass Changes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrappage/Sales Impacts	-0.1	-0.1	-0.2	-0.2	-0.2	-0.1	-0.1
Subtotal	***-0.1***	***-0.1***	***-0.2***	***-0.2***	***-0.2***	***-0.1***	***-0.1***
Rebound Effect	-3.0	-3.0	-2.5	-2.4	-1.8	-1.6	-1.1
Total	**-3.2**	**-3.1**	**-2.7**	**-2.6**	**-2.0**	**-1.7**	**-1.2**

Table I-175 - Change in Safety Parameters from Augural CAFE Standards Baseline
Average Annual Fatalities, CY 2036-2045, 7% Discount Rate

	Alternative						
	1	2	3	4	5	6	7
Model Years	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities							
Mass Changes	-3	-3	-3	-3	-2	-2	-1
Scrappage/Sales Impacts	-12	-13	-17	-18	-17	-13	-9
Subtotal	***-16***	***-16***	***-20***	***-21***	***-19***	***-15***	***-11***
Rebound Effect	-333	-327	-280	-265	-201	-172	-123
Total	***-349***	***-343***	***-300***	***-286***	***-220***	***-187***	***-133***
Fatality Costs ($b)							
Mass Changes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrappage/Sales Impacts	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	***0.0***	***0.0***	***0.0***	***-0.1***	***0.0***	***0.0***	***0.0***
Rebound Effect	-0.8	-0.8	-0.7	-0.7	-0.5	-0.4	-0.3
Total	***-0.9***	***-0.9***	***-0.7***	***-0.7***	***-0.5***	***-0.5***	***-0.3***
Non Fatal Crash Costs ($b)							
Mass Changes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrappage/Sales Impacts	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	0.0
Subtotal	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***0.0***
Rebound Effect	-1.4	-1.3	-1.1	-1.1	-0.8	-0.7	-0.5
Total	***-1.4***	***-1.4***	***-1.2***	***-1.2***	***-0.9***	***-0.8***	***-0.5***

Table I-176 - Change in Safety Parameters from Augural CAFE Standards Baseline
Total Fatalities MY 1977-2029, 3% Discount Rate

	Alternative						
	1	2	3	4	5	6	7
Model Years	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities							
Mass Changes	-20	-20	-18	-18	-13	-13	-10
Scrappage/Sales Impacts	-541	-532	-455	-452	-343	-304	-182
Subtotal	***-561***	***-552***	***-474***	***-471***	***-355***	***-318***	***-192***
Rebound Effect	-3226	-3162	-2736	-2614	-1866	-1766	-1201
Total	***-3788***	***-3714***	***-3210***	***-3084***	***-2222***	***-2084***	***-1393***
Fatality Costs ($b)							
Mass Changes	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Scrappage/Sales Impacts	-4.6	-4.5	-3.9	-3.8	-2.9	-2.7	-1.7
Subtotal	***-4.7***	***-4.6***	***-4.0***	***-4.0***	***-3.0***	***-2.8***	***-1.8***
Rebound Effect	-22.8	-22.3	-19.4	-18.5	-13.2	-12.6	-8.5
Total	***-27.5***	***-27.0***	***-23.4***	***-22.5***	***-16.2***	***-15.3***	***-10.3***
Non Fatal Crash Costs ($b)							
Mass Changes	-0.2	-0.2	-0.2	-0.2	-0.1	-0.2	-0.1
Scrappage/Sales Impacts	-7.6	-7.4	-6.4	-6.4	-4.8	-4.5	-2.8
Subtotal	***-7.8***	***-7.7***	***-6.6***	***-6.6***	***-5.0***	***-4.6***	***-3.0***
Rebound Effect	-37.6	-36.8	-32.0	-30.6	-21.7	-20.7	-14.0
Total	**-45.4**	**-44.5**	**-38.6**	**-37.1**	**-26.7**	**-25.3**	**-17.0**

Table I-177 - Change in Safety Parameters from Augural CAFE Standards Baseline
Total Fatalities MY 1977-2029, 7% Discount Rate

	Alternative						
	1	2	3	4	5	6	7
Model Years	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities							
Mass Changes	-20	-20	-18	-18	-13	-13	-10
Scrappage/Sales Impacts	-541	-532	-455	-452	-343	-304	-182
Subtotal	***-561***	***-552***	***-474***	***-471***	***-355***	***-318***	***-192***
Rebound Effect	-3226	-3162	-2736	-2614	-1866	-1766	-1201
Total	***-3788***	***-3714***	***-3210***	***-3084***	***-2222***	***-2084***	***-1393***
Fatality Costs ($b)							
Mass Changes	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0
Scrappage/Sales Impacts	-3.5	-3.4	-3.0	-3.0	-2.2	-2.1	-1.4
Subtotal	***-3.6***	***-3.5***	***-3.0***	***-3.0***	***-2.3***	***-2.2***	***-1.4***
Rebound Effect	-14.6	-14.3	-12.5	-11.9	-8.4	-8.1	-5.4
Total	***-18.1***	***-17.8***	***-15.5***	***-14.9***	***-10.7***	***-10.3***	***-6.9***
Non Fatal Crash Costs ($b)							
Mass Changes	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Scrappage/Sales Impacts	-5.8	-5.7	-4.9	-4.9	-3.7	-3.5	-2.3
Subtotal	***-5.9***	***-5.8***	***-5.1***	***-5.0***	***-3.8***	***-3.6***	***-2.4***
Rebound Effect	-24.1	-23.6	-20.6	-19.7	-13.8	-13.4	-9.0
Total	**-30.0**	**-29.4**	**-25.6**	**-24.7**	**-17.6**	**-17.0**	**-11.4**

Table I-178 - Change in Safety Parameters from Augural CO_2 Standards Baseline
Average Annual Fatalities, CY 2036-2045, 3% Discount Rate

	Alternative						
	1	2	3	4	5	6	7
Model Years	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities							
Mass Changes	-3	-3	-2	-2	-2	-2	-2
Scrappage/Sales Impacts	-13	-10	-9	-9	-10	-13	-12
Subtotal	***-16***	***-13***	***-12***	***-11***	***-12***	***-15***	***-14***
Rebound Effect	-389	-376	-309	-291	-218	-192	-128
Total	***-405***	***-389***	***-320***	***-302***	***-231***	***-207***	***-142***
Fatality Costs ($b)							
Mass Changes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrappage/Sales Impacts	-0.1	-0.1	-0.1	0.0	-0.1	-0.1	-0.1
Subtotal	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***
Rebound Effect	-2.2	-2.1	-1.7	-1.6	-1.2	-1.1	-0.7
Total	***-2.2***	***-2.2***	***-1.8***	***-1.7***	***-1.3***	***-1.1***	***-0.8***
Non Fatal Crash Costs ($b)							
Mass Changes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrappage/Sales Impacts	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Subtotal	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***	***-0.1***
Rebound Effect	-3.5	-3.4	-2.8	-2.6	-2.0	-1.7	-1.2
Total	***-3.7***	***-3.5***	***-2.9***	***-2.7***	***-2.1***	***-1.9***	***-1.3***

Table I-179 - Change in Safety Parameters from Augural CO_2 Standards Baseline
Average Annual Fatalities, CY 2036-2045, 7% Discount Rate

	Alternative						
	1	2	3	4	5	6	7
Model Years	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities							
Mass Changes	-3	-3	-2	-2	-2	-2	-2
Scrappage/Sales Impacts	-13	-10	-9	-9	-10	-13	-12
Subtotal	***-16***	***-13***	***-12***	***-11***	***-12***	***-15***	***-14***
Rebound Effect	-389	-376	-309	-291	-218	-192	-128
Total	***-405***	***-389***	***-320***	***-302***	***-231***	***-207***	***-142***
Fatality Costs ($b)							
Mass Changes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrappage/Sales Impacts	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***
Rebound Effect	-1.0	-0.9	-0.8	-0.7	-0.5	-0.5	-0.3
Total	***-1.0***	***-1.0***	***-0.8***	***-0.7***	***-0.6***	***-0.5***	***-0.4***
Non Fatal Crash Costs ($b)							
Mass Changes	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Scrappage/Sales Impacts	-0.1	0.0	0.0	0.0	0.0	-0.1	0.0
Subtotal	***-0.1***	***-0.1***	***0.0***	***0.0***	***0.0***	***-0.1***	***-0.1***
Rebound Effect	-1.6	-1.5	-1.2	-1.2	-0.9	-0.8	-0.5
Total	**-1.6**	**-1.6**	**-1.3**	**-1.2**	**-0.9**	**-0.8**	**-0.6**

Table I-180 - Change in Safety Parameters from Augural CO_2 Standards Baseline
Total Fatalities MY 1977-2029, 3% Discount Rate

	Alternative						
	1	2	3	4	5	6	7
Model Years	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities							
Mass Changes	-18	-17	-17	-17	-14	-15	-14
Scrappage/Sales Impacts	-546	-512	-455	-427	-344	-358	-300
Subtotal	***-564***	***-529***	***-471***	***-444***	***-359***	***-373***	***-314***
Rebound Effect	-3332	-3224	-2694	-2567	-1884	-1887	-1342
Total	***-3896***	***-3754***	***-3166***	***-3010***	***-2243***	***-2260***	***-1656***
Fatality Costs ($b)							
Mass Changes	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Scrappage/Sales Impacts	-4.3	-4.0	-3.6	-3.4	-2.7	-2.9	-2.3
Subtotal	***-4.4***	***-4.1***	***-3.7***	***-3.5***	***-2.8***	***-3.0***	***-2.4***
Rebound Effect	-23.5	-22.7	-19.1	-18.2	-13.3	-13.4	-9.6
Total	***-27.9***	***-26.9***	***-22.8***	***-21.7***	***-16.1***	***-16.4***	***-12.0***
Non Fatal Crash Costs ($b)							
Mass Changes	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2
Scrappage/Sales Impacts	-7.1	-6.7	-6.0	-5.6	-4.5	-4.7	-3.8
Subtotal	***-7.3***	***-6.9***	***-6.2***	***-5.8***	***-4.6***	***-4.9***	***-4.0***
Rebound Effect	-38.7	-37.5	-31.4	-29.9	-21.9	-22.2	-15.8
Total	**-46.0**	**-44.3**	**-37.6**	**-35.7**	**-26.6**	**-27.1**	**-19.8**

Table I-181 - Change in Safety Parameters from Augural CO_2 Standards Baseline
Total Fatalities MY 1977-2029, 7% Discount Rate

	Alternative						
	1	2	3	4	5	6	7
Model Years	2021-2026	2021-2026	2021-2026	2021-2026	2022-2026	2021-2026	2022-2026
Annual Rate of Stringency Increase	0.0%/Year PC 0.0%/Year LT	0.5%/Year PC 0.5%/Year LT	1.5%/Year PC 1.5%/Year LT	1.0%/Year PC 2.0%/Year LT	1.0%/Year PC 2.0%/Year LT	2.0%/Year PC 3.0%/Year LT	2.0%/Year PC 3.0%/Year LT
Fatalities							
Mass Changes	-18	-17	-17	-17	-14	-15	-14
Scrappage/Sales Impacts	-546	-512	-455	-427	-344	-358	-300
Subtotal	***-564***	***-529***	***-471***	***-444***	***-359***	***-373***	***-314***
Rebound Effect	-3332	-3224	-2694	-2567	-1884	-1887	-1342
Total	***-3896***	***-3754***	***-3166***	***-3010***	***-2243***	***-2260***	***-1656***
Fatality Costs ($b)							
Mass Changes	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Scrappage/Sales Impacts	-3.1	-2.9	-2.6	-2.5	-2.0	-2.1	-1.6
Subtotal	***-3.1***	***-3.0***	***-2.7***	***-2.6***	***-2.0***	***-2.2***	***-1.7***
Rebound Effect	-15.0	-14.5	-12.2	-11.6	-8.5	-8.7	-6.2
Total	***-18.1***	***-17.5***	***-14.9***	***-14.2***	***-10.5***	***-10.9***	***-7.9***
Non Fatal Crash Costs ($b)							
Mass Changes	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
Scrappage/Sales Impacts	-5.1	-4.8	-4.4	-4.1	-3.2	-3.5	-2.7
Subtotal	***-5.2***	***-5.0***	***-4.5***	***-4.2***	***-3.3***	***-3.6***	***-2.8***
Rebound Effect	-24.7	-23.9	-20.2	-19.2	-14.0	-14.3	-10.3
Total	**-29.9**	**-28.9**	**-24.7**	**-23.4**	**-17.4**	**-17.9**	**-13.1**

These tables present aggregations or averages of results for calendar years through 2050. Underlying model output files provide results for each model year in each calendar year.[1586] These results can be used for more detailed review and analysis of estimated trends. For example, for each calendar year through 2050, the following two tables — one for CAFE standards and one for CO_2 standards — show (a) the number of light-duty vehicles in service, (b) the travel accumulated by those vehicles, and (c) the total number fatalities among the types included in today's analysis.

Under the preferred alternative, the analysis shows the annual number of fatalities growing more slowly than under the baseline standards, reflecting the combined effects of fleet turnover, mass reduction, and shifts between passenger cars and light trucks in the new vehicle fleet.

The Pennsylvania Department of Environmental Protection commented that the agencies did not fully account for safety improvements associated with the augural standards.[1587] The agencies note that the analysis accounts for the safety impacts of mass reduction, sales and scrappage, rebound, vehicle model year and vehicle age for each of the alternatives relative to the augural baseline. The commenter did not provide any specific items that were omitted from the analysis. The agencies believe the analysis thoroughly assesses the safety effects of all of the alternatives.

3. Simulating Environmental Impacts of Regulatory Alternatives

[text forthcoming].

E. Compliance example walk-through

To illustrate the CAFE model's simulation of a manufacturer's potential response to fuel prices and new standards, the NPRM provided an example of how that the preliminary version of the model showed, on a year-by-year basis, how GM could potentially respond to a set of CAFE standards, starting from MY 2016 (the latest year for which the agencies were able to develop a full and detailed characterization of the fleet of vehicles produced for sale in the U.S. at the time of publishing the NPRM). Although no analysis that does not rely heavily on a manufacturer's confidential product planning information can, with high fidelity, predict what that manufacturer *will* do, the CAFE model, by realistically reflecting product planning considerations in a detailed year-by-year context, can describe a course that manufacturer *could* realistically take. Indeed, when manufacturers provide information to the agencies, they often emphasize year-by-year plans. Although such information is typically considered confidential business information (CBI), public comments by the Alliance illustrate the concept for a hypothetical manufacturer. Although the illustration includes credit carry-back (aka borrowing) that most manufacturers have a history of avoiding, the illustration clearly demonstrates that the Alliance views product planning as a year-by-year exercise:

[1586] Available at https://www.nhtsa.gov/corporate-average-fuel-economy/compliance-and-effects-modeling-system.
[1587] Pennsylvania Department of Environmental Protection, Detailed Comments, Docket No. NHTSA-2018-0067-11956, at 8-9.

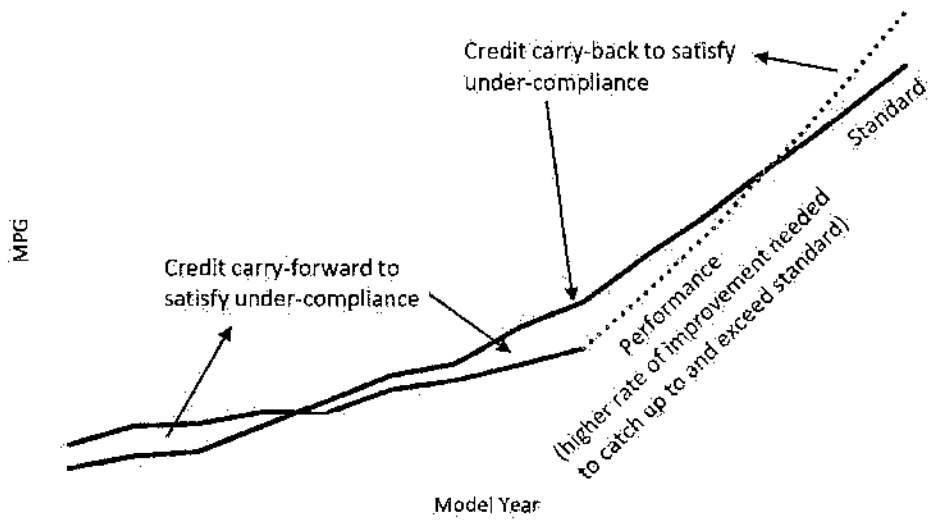

Figure VI-60 – Alliance Illustration of a Hypothetical OEM's Compliance Pathway[1588]

Like the peer reviewers who examined the model's simulation of technology application and compliance, automakers have been widely supportive of the CAFE model's approach of year-by-year analysis informed by product planning realities. For example, Toyota commented, "The preamble correctly notes that manufacturers try to keep costs down by applying most major changes mainly during vehicle redesigns and more modest changes during product refresh, and that redesign cycles for vehicle models can range from six to ten years, and eight to ten-years for powertrains… This appreciation for standard business practice enables the modeling to capture more accurately the way vehicles share engines, transmissions, and platforms. There are now more realistic limits placed on the number of engines and transmissions in a powertrain portfolio which better recognizes manufacturers must manage limited engineering resources and control supplier, production, and service costs."[1589]

The CAFE model's year-by-year approach to estimating manufacturers' potential responses to standards and fuel prices is consistent with EPCA/EISA's requirement that CAFE standards be set at the maximum feasible levels for each fleet (passenger car and light truck) in each model year. Some commenters correctly observe that the CAA (which provides no direction regarding tailpipe CO_2 emissions standards) does not require such a year-by-year determination, but suggest, further, that EPA should refrain from making use of year-by-year analysis. In particular, CBD et. al. commented as follows:

[1588] NHTSA-2018-0067-12073, at 28.
[1589] NHTSA-2018-0067-12098, at 6.

> Furthermore, the Volpe model and association [sic] tools are not designed in accordance with EPA's independent statutory authority under Clean Air Act Section 202. The Volpe and OMEGA models have an overarching difference in their architecture—one where the Volpe modeling approach is designed to match NHTSA's statutory authority, but not EPA's. The EPCA requirements drive the design of the Volpe model, in that it performs a year-by-year analysis in order to demonstrate that NHTSA is meeting its EPCA obligations. As a result, the Volpe model attempts to simulate for each manufacturer, by year, their refresh and redesign cadence across their vehicle platforms and then predict a manufacturer's technology deployment decision-making process for each platform. But under the Clean Air Act, EPA is not required to demonstrate that standards are set at the maximum feasible level year-by-year, as EPCA explicitly requires for NHTSA.[1590]

Although CBD is correct that the CAA does not *require* a year-by-year determination or year-by-year analysis, CBD wrongly claims that the CAFE model's modeling approach is not "in accordance" with the CAA. ~~CBD's claim is analogous to saying "just say you want to drive across the country; don't bother looking at a map."~~ As the NPRM demonstrated, the CAFE model can be used to simulate compliance with CO_2 standards. That the model follows a year-by-year approach to doing so simply means that it ~~takes greater pains to describe~~attempts to project realistic pathways forward from a known model year. Manufacturers are ~~by no means~~not the only stakeholders to recognize that product planning is actually a year-by-year process. Supporting its comments on the agencies' proposal, CARB provided a study by Roush Industries, focusing on a potential design pathway for the Toyota RAV4.[1591] While this report, which was cited by CARB in its comments, asserted the agencies' modeling underestimated fuel consumption benefits and overestimated costs, Roush, like the Alliance, clearly interpreted the question of realism as a year-by-year question, as illustrated by the following chart in Roush's report:

Commented [A413]: DELETE: This is disparanging to the public commenter, and unnecessary to respond to the substance of the comment.

Other edits in this paragraph are to provide a more factual tone, not overreaching.

[1590] NHTSA-2018-0067-12000, Appendix A, at 24-25.

[1591] Rogers, G., "Technical Review of: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks, Final Report." Roush Industries. October 25, 2018. *See* CARB, NHTSA-2018-0067-11984.

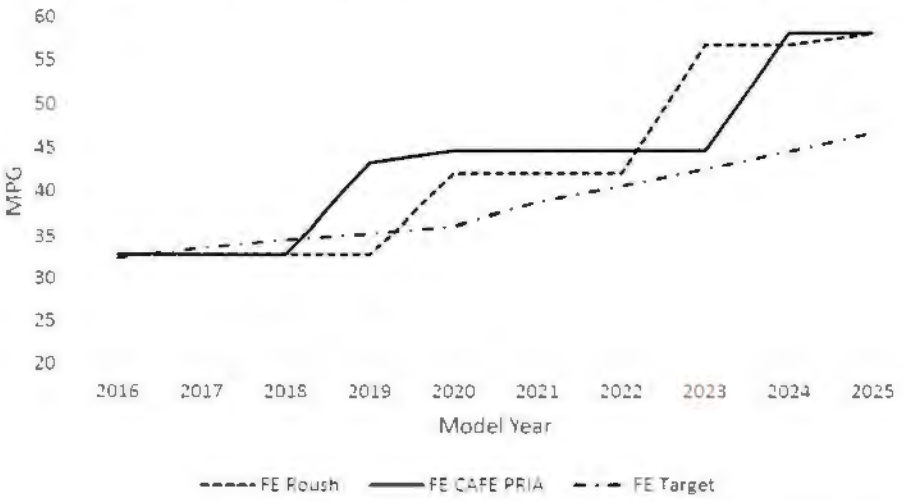

Figure VI-61 – Roush Industries Illustration (for CARB) of RAV4 Fuel Economy Pathway[1592]

While a year-by-year representation is ~~essential~~ one advantageous way to ~~the~~ estimat~~ions of~~ pathways that individual manufacturers could realistically take to apply technologies to specific vehicle models, the CAFE model also accounts for a range of other important engineering and product planning considerations. For example, among specific vehicle models, engines and transmissions are often shared, and a given vehicle design platform may encompass a range of different specific vehicle models. This means not every configuration of every vehicle model can be as optimized for fuel economy as if each could be considered in isolation. This isn't to say that such optimization is technologically impossible, but rather to say that the resources involved in such optimization would be financially impracticable. Moreover, CAFE and CO_2 standards apply to fleets, not specific products. This means, for example, that if a given engine is shared among both passenger cars and light trucks, changes made to that engine in response to one fleet's standard will impact products in the other fleet. Consistent with the fact that CAFE and CO_2 compliance applies to fleets on a year-by-year basis, the CAFE model explicitly accounts for sharing among specific model/configurations when simulating year-by-year compliance. The Rousb report's authors "have not performed a complete fleet-compliance simulation."[1593] Therefore, even notwithstanding differences in estimates of redesign schedules and technology efficacy and costs, Roush's analysis of the RAV4 is highly idealized. As discussed below, together with inputs based on Toyota's actual MY 2017 production, the CAFE model represents the RAV4 as encompassing multiple configurations, spanning both the

[1592] Rogers, G., "Technical Review of: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021-2026 Passenger Cars and Light Trucks, Final Report," at 26. Roush Industries. October 25, 2018. *See* CARB, NHTSA-2018-0067-11984.
[1593] *Ibid.* at 6.

passenger car and light truck regulatory classes, all on a common vehicle platform that includes several other vehicle models, and some RAV4s sharing engines with some Camrys. Compared to estimating the *potential* to apply technology to a handful of specific model/configurations in isolation, analysis that accounts for manufacturers' *actual* production considerations produces more realistic results.

~~Nothing about the CAA discourages realism in regulatory analysis, and even if the CAA did so, the CAFE model can easily be run for isolated model years, or run in a manner that otherwise ignores practical limits on development and manufacturing complexity.[1594]~~ EPA elected to use the CAFE model ~~as designed~~ because doing so produces a ~~more~~ reasonable ~~realistic~~ basis to estimate regulatory impacts. EPA considers its use of the CAFE model entirely consistent with all CAA and other statutory and other requirements governing the agency's development of motor vehicle CO2 emissions standards, ~~which, unlike criteria pollutant standards, are specified on a year-by-year basis, and inherently involve the entirety of manufacturers' vehicles and fleets.~~

Commented [A414]: **CHANGE AS SHOWN**: Factually correcting the CAA authority and the basis for the Administrator's decision to use the CAFE model as communicated in the NPRM. Also editing tone which is unnecessary to make the point.

Of course, like any other model, the CAFE model used for the NPRM had room for improvement. As discussed above, the agencies have responded to public comments by making changes to some aspects of the CAFE model itself. Only a few such changes, all of which are discussed above in greater detail, impact the CAFE model's simulation of manufacturers' application of fuel-saving technologies. Among these, three are especially important: First, the model now uses a more "open" application of its technology "decision trees." While the primary objective of this change is to make the model's cost accounting more transparent (by recasting costs as absolute rather than incremental), it also makes the model somewhat more likely to identify and apply any highly cost-effective yet comparatively "advanced" combinations of technology. Second, the model introduces a "cost per credit" metric for comparing available opportunities to add specific technologies to specific vehicles.[1595] As discussed above and in the summary of the sensitivity analysis conducted for today's notice, changing from the NPRM's "effective cost" metric to this new "cost per credit" metric leads the model to, at least for the combination of inputs in today's central analysis, select less costly technology pathways. Third, the CAFE model can now extend its explicit simulation of manufacturers' technology application well into the future. Today's analysis extends this explicit simulation through model year 2050. Because today's reference case input estimates include continued increases in fuel prices alongside continued ("learning"-related) reductions in technology costs, extending the explicit simulation shows manufacturers making significant voluntary improvement in the longer term (e.g., after MY 2035), even if CAFE and CO_2 remain unchanged.

The agencies have also revised most of the inputs to the CAFE model, both to respond to comments and to better reflect an ever-changing world. Sections appearing above discuss

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~~[1594] Idealized simulation of compliance with a hypothetically isolated model year could be accomplished by, when running the model, setting the various "start" and "end" years to the same value. Sharing of engines and transmission among different model configurations could be ignored by, in the CAFE model's "market" input file, assigning each engine, transmission, and vehicle platform to a single model configuration (e.g., such that each of the six versions of the RAV4 is on its own vehicle platform, and uses a dedicated engine and transmission).~~

[1595] Notable comments on this metric appear at NHTSA-2018-0067-12039, Appendix, pp. 28-34, and at NHTSA-2018-0067-12108, Appendix B, pp. 66-70.

changes to model inputs, such as the analysis fleet, technology-related inputs, and fuel prices. Many of these changes are important to the model's simulated application of fuel-saving technology. Updating the analysis fleet from a MY 2016 to a MY 2017 basis ensures that fuel economy and CO_2 improvements manufacturers *actually* realized by adding technologies between those model years is accounted for, and ensures that changes in product offerings and production volumes between those model years are also accounted for. With this update, the agencies also more fully accounted for compliance credits accumulated prior to the MYs represented explicitly in today's analysis. Some manufacturers have accumulated large volumes of such credits, and are able to apply those credits well past MY 2016, and to trade them to other manufacturers. Updated vehicle simulations correct errors and make use of additional engine performance estimates (i.e., engine efficiency "maps"), and cost estimates for some technologies reflect additional data and consideration of comments. Also, fuel prices in the forecast used for today's analysis are somewhat higher than those used for the NPRM; by itself, this change makes the model tend to show larger and more widespread voluntary fuel economy increases and accompanying CO_2 emissions reductions, although this increased tendency is countered by the impact of changing to the "cost per credit" metric.

The following example will illustrate the model's behavior when simulating compliance with CO_2 standards. While the example focuses on a the baseline CO_2 standards and on a specific manufacturer (Toyota), and highlights a specific vehicle model (the Toyota RAV4), results for other scenarios, manufacturers, and vehicle models reflect application of the same logic. Because this example begins with the MY 2017 fleet, and does not make use of manufacturers' product plans (which the agencies have historically treated as confidential business information, today's analysis cannot and does not fully reflect manufacturers' actual product design decisions, even in the short term. Nevertheless, the analysis yields a realistic and detailed characterization of a path each manufacturer could take in response to a given set of standards and other input estimates (e.g., of technology costs and fuel prices).

As discussed above, the model considers all models and model/configurations produced for sale in the U.S. by a given manufacturer. The Toyota Camry and Tundra are examples of specific Toyota passenger car and light truck models, Toyota produces a range of configurations (e.g., with different engines) of each of these vehicle models, and inputs to the CAFE model ensure that each such configuration is accounted for. CAFE model output files show the progressive application of technology to each model/configuration over time under each regulatory alternative. Here, focusing on different versions of one model, the RAV4, illustrates the process and results.

The RAV4 is one of the vehicle models included in a vehicle platform that also includes the Camry, Corolla, Prius, Lexus CT 200h, Lexus NX 200t, and Lexus NX 300h. As mentioned above, the CAFE model reflects the agencies' assumption that significant changes to vehicle structures or materials will most practicably be applied throughout a vehicle platform as models within the platform are redesigned. Within this platform, the CAFE model identifies the Corolla LE, at more than 180,000 units produced in MY 2017, as the most likely "leader" for such changes. Inputs to today's analysis also show that most of the RAV4s produced for the U.S. in MY 2017 shared a 2.5L naturally aspirated 4-cylinder gasoline engine with many Camrys. The CAFE model identifies the Camry as the leader for new versions of that engine. The same inputs

show many RAV4s shared a 6-speed automatic transmission with a range of other vehicle models, including the Avalon, Camry, Lexus ES 350, Highlander, Lexus NX 200t, and the CAFE model identifies the Camry as the most likely leader for changes to this transmission. Model inputs also show other RAV4s shared a different 6-speed automatic transmission with the Lexus NX 200t, and the CAFE model identifies the RAV4 as the most likely leader for changes to this transmission. Finally, the MY2017 RAV4 also included two "strong" (power split) hybrid-electric versions (SE and XLE). Although these shared an engine with other Toyota hybrids (Avalon, Camry, Lexus ES 300h and NX 300h), the CAFE model reflects the agencies' assumption that it could be practicable to "split off" plug-in (or fuel cell) configurations rather than necessarily replace all strong hybrids sharing an engine with PHEVs, BEVs, or FCVs.

Inputs for today's analysis have Toyota redesigning the RAV4 every five years, starting with MY 2019, and freshening the model 2-3 years after each redesign. Given this design cycle, and all the other inputs to today's analysis, the CAFE model shows that under the baseline CO_2 standards, Toyota could potentially make changes to the RAV4 summarized in the table that follows. The first changes occur in 2019, with Toyota improving aerodynamics of the hybrid RAV4s, and with the conventional RAV4s inheriting a new high compression ratio (HCR) engine introduced with the MY 2018 redesign of the Camry, and also adding 8-speed automatic (A8) transmissions,[1596] improved accessories (IACC), and tires with reduced rolling resistance (ROLL20). With the MY 2024 redesign, conventional RAV4s inherit the aerodynamic improvements (AERO15) from the 2019 hybrid RAV4, hybrid RAV4s receive further such improvements (AERO20), engine friction reduction (EFR) is applied to the HCR engine shared with the Camry, and "Level 1" mass reduction (MR1) is applied to all the RAV4s. With the MY 2027 freshening, Toyota applies low-drag brakes to all the RAV4s. The MY 2029 redesign does not make any powertrain changes, but applies significant mass reduction (MR4) to all RAV4s. In MY 2033, Toyota replaces the hybrid RAV4 SE with a 200-mile electric vehicle (BEV200), and in MY 2039, Toyota replaces the hybrid RAV4 XLE with a 300-mile EV (BEV300).

Table-VI-182 - Estimated RAV4 Technology Application under Baseline CO_2 Standards

Model Year	Design State	Added Technologies (vs. Prior)
2017		Non-Hybrid Versions: 2.5L DOHC VVLT NA I4 (shared), A6 (shared) with EPS
2018		Hybrid Versions: "Strong" HEV (Power Split) with IACC and LDB
2019	Redesign	Non-Hybrid Versions: HCR1 (inherited from 2018 Camry) and AT8, IACC, ROLL20 Hybrid Versions: AERO15
2020		
2021		
2022	Refresh	
2023		
2024	Redesign	Non-Hybrid Versions: EFR (2024 Camry version), AERO15, MR1 Non-Hybrid AWD Versions: SAX Hybrid Versions: AERO20, MR1
2025		
2026		
2027	Refresh	Non-Hybrid Versions: LDB

[1596] While it is not necessary for the compliance simulation to produce real predictions of manufacturer product designs, only plausible ones, these changes to the RAV4 did in fact occur during the 2019 redesign.

2028		
2029	Redesign	All Versions: MR4
2030		
2031		
2032	Refresh	
2033		
2034	Redesign	Hybrid SE: BEV200
2035		
2036		
2037	Refresh	
2038		
2039	Redesign	Hybrid XLE: BEV300
2040		
2041		
2042	Refresh	
2043		
2044	Redesign	
2045		
2046	Refresh	
2047		
2048		
2049	Redesign	
2050		

This progressive application of technology to the RAV4 produces a series of emission reductions shown in the following table (and, though not shown, corresponding fuel economy improvements). The table also shows the progression of CO_2 targets for these vehicles, reflecting the fact that targets are higher for the hybrid and conventional AWD versions of the RAV4, classified as light trucks, than for the FWD RAV4s classified as passenger cars. Also notably, the conventional RAV4s never achieve their respective CO_2 emissions targets. This merely reflects the fact that credits for reducing A/C refrigerant leakage apply at the fleet level rather than on a per-vehicle basis and, in any event, Toyota can respond by improving CO_2 levels enough among enough other vehicle models that Toyota's overall average CO_2 levels comply with Toyota's overall requirements, taking into account the potential application of compliance credits.

Table-VI-183 - Estimated RAV4 Target/Achieved CO_2 Levels (g/mi) under Baseline CO_2 Standards

Model Year	Design State	RAV4 Versions						
		Limited and SE FWD	LE and XLE AWD	Hybrid SE	Hybrid XLE	LE and XLE FWD	LE and XLE AWD	Limited and SE AWD
2017		212/262	257/270	256/199	257/199	214/255	256/275	256/275
2018		203/262	245/270	244/199	245/199	204/255	244/275	244/275

2019	Redesign	194/212	238/219	236/175	238/175	195/206	236/223	236/223
2020		185/212	230/219	228/175	230/175	186/206	228/223	228/223
2021		175/212	212/219	211/175	212/175	176/206	211/223	211/223
2022	Refresh	167/212	202/219	200/175	202/175	168/206	200/223	200/223
2023		159/212	192/219	191/175	192/175	160/206	191/223	191/223
2024	Redesign	151/198	182/202	181/169	182/169	152/193	181/206	181/206
2025		144/198	173/202	172/169	173/169	145/193	172/206	172/206
2026		144/198	173/202	172/169	173/169	145/193	172/206	172/206
2027	Refresh	144/197	173/195	172/166	173/166	145/191	172/199	172/199
2028		144/197	173/195	172/166	173/166	145/191	172/199	172/199
2029	Redesign	144/187	173/185	172/159	173/159	145/181	172/189	172/189
2030		144/187	173/185	172/159	173/159	145/181	172/189	172/189
2031		144/187	173/185	172/159	173/159	145/181	172/189	172/189
2032	Refresh	144/187	173/185	172/159	173/159	145/181	172/189	172/189
2033		144/187	173/185	172/159	173/159	145/181	172/189	172/189
2034	Redesign	144/187	173/185	172/92	173/159	145/181	172/189	172/189
2035		144/187	173/185	172/92	173/159	145/181	172/189	172/189
2036		144/187	173/185	172/92	173/159	145/181	172/189	172/189
2037	Refresh	144/187	173/185	172/92	173/159	145/181	172/189	172/189
2038		144/187	173/185	172/92	173/159	145/181	172/189	172/189
2039	Redesign	144/187	173/185	172/92	173/96	145/181	172/189	172/189
2040		144/187	173/185	172/92	173/96	145/181	172/189	172/189
2041		144/187	173/185	172/92	173/96	145/181	172/189	172/189
2042	Refresh	144/187	173/185	172/92	173/96	145/181	172/189	172/189
2043		144/187	173/185	172/92	173/96	145/181	172/189	172/189
2044	Redesign	144/187	173/185	172/92	173/96	145/181	172/189	172/189
2045		144/187	173/185	172/92	173/96	145/181	172/189	172/189
2046	Refresh	144/187	173/185	172/92	173/96	145/181	172/189	172/189
2047		144/187	173/185	172/92	173/96	145/181	172/189	172/189
2048		144/187	173/185	172/92	173/96	145/181	172/189	172/189
2049	Redesign	144/187	173/185	172/92	173/96	145/181	172/189	172/189
2050		144/187	173/185	172/92	173/96	145/181	172/189	172/189

These CO_2 values could be converted to equivalent fuel economy levels by multiplying their reciprocals by 8887 grams per gallon (e.g., 8887 g/gal × 1/(144 g/mi) = 62 mpg), differences in compliance provisions are such that results would be offset from actual fuel economy levels under CAFE standards. When simulating compliance with CAFE or CO_2 standards, the CAFE model reports both fuel economy and CO_2 targets and achieved levels, even when the model is "enforcing" compliance with only one of these sets of standards. When simulating compliance with baseline CO_2 standards, results for the example discussed here show the following fuel economy targets and achieved levels for the RAV4.

Table-VI-184 - Estimated RAV4 Target/Achieved FE Levels (mpg) under Modeled Response to Baseline CO_2 Standards

Model Year	Design State	RAV4 Versions						
		Limited and SE FWD	LE and XLE AWD	Hybrid SE	Hybrid XLE	LE and XLE FWD	LE and XLE AWD	Limited and SE AWD
2017		40/34	34/33	34/45	34/45	40/35	34/32	34/32
2018		42/34	35/33	35/45	35/45	42/35	35/32	35/32
2019	Redesign	43/42	35/41	36/51	35/51	43/43	36/40	36/40
2020		45/42	36/41	36/51	36/51	45/43	36/40	36/40
2021		47/42	39/41	39/51	39/51	47/43	39/40	39/40
2022	Refresh	49/42	41/41	41/51	41/51	49/43	41/40	41/40
2023		52/42	43/41	43/51	43/51	51/43	43/40	43/40
2024	Redesign	54/45	45/44	45/53	45/53	54/46	45/43	45/43
2025		56/45	47/44	47/53	47/53	56/46	47/43	47/43
2026		56/45	47/44	47/53	47/53	56/46	47/43	47/43
2027	Refresh	56/45	47/45	47/53	47/53	56/46	47/45	47/45
2028		56/45	47/45	47/53	47/53	56/46	47/45	47/45
2029	Redesign	56/48	47/48	47/56	47/56	56/49	47/47	47/47
2030		56/48	47/48	47/56	47/56	56/49	47/47	47/47
2031		56/48	47/48	47/56	47/56	56/49	47/47	47/47
2032	Refresh	56/48	47/48	47/56	47/56	56/49	47/47	47/47
2033		56/48	47/48	47/56	47/56	56/49	47/47	47/47
2034	Redesign	56/48	47/48	47/336	47/56	56/49	47/47	47/47
2035		56/48	47/48	47/336	47/56	56/49	47/47	47/47
2036		56/48	47/48	47/336	47/56	56/49	47/47	47/47
2037	Refresh	56/48	47/48	47/336	47/56	56/49	47/47	47/47
2038		56/48	47/48	47/336	47/56	56/49	47/47	47/47
2039	Redesign	56/48	47/48	47/336	47/325	56/49	47/47	47/47
2040		56/48	47/48	47/336	47/325	56/49	47/47	47/47
2041		56/48	47/48	47/336	47/325	56/49	47/47	47/47
2042	Refresh	56/48	47/48	47/336	47/325	56/49	47/47	47/47
2043		56/48	47/48	47/336	47/325	56/49	47/47	47/47
2044	Redesign	56/48	47/48	47/336	47/325	56/49	47/47	47/47
2045		56/48	47/48	47/336	47/325	56/49	47/47	47/47
2046	Refresh	56/48	47/48	47/336	47/325	56/49	47/47	47/47
2047		56/48	47/48	47/336	47/325	56/49	47/47	47/47
2048		56/48	47/48	47/336	47/325	56/49	47/47	47/47
2049	Redesign	56/48	47/48	47/336	47/325	56/49	47/47	47/47
2050		56/48	47/48	47/336	47/325	56/49	47/47	47/47

The progressive application of technology also produces increases (and some eventual decreases) in costs. For each RAV4 configuration, the following table shows costs beyond MY

2017 technology, in 2018 dollars. The conventional RAV4s incur a significant cost increase in MY 2019, primarily for the new HCR engine inherited from the Camry. Costs continue to increase through MY 2029 as additional technology accumulates, with another significant increase for MR4 in MY 2029. After MY 2029, technology costs for conventional RAV4s gradually decline through MY 2050, in response to ongoing learning. In MY 2034, the BEV200 RAV4 is *less* expensive than the HEV RAV4 it replaces, leading this version's cost to drop by about $500 between MY 2033 and MY 2034, and with learning, to fall quickly well below this version's MY *2017* cost. Conversely, the BEV300 RAV4 introduced in MY 2039 is about $850 more expensive than the MY 2038 hybrid RAV4 it replaces, and even with learning, the BEV300 remains more expensive than the hybrid RAV4. These BEVs are not needed for compliance; the model shows Toyota could introduce them because, if battery costs continue to decline while gasoline prices continue to increase, BEVs could eventually become attractive on an economic basis.

Table-VI-185 - Estimated RAV4 Technology Costs (2018 Dollars) vs. MY 2017 under Baseline CO_2 Standards

Model Year	Design State	RAV4 Versions						
		Limited and SE FWD	LE and XLE AWD	Hybrid SE	Hybrid XLE	LE and XLE FWD	LE and XLE AWD	Limited and SE AWD
2017		-	-	-	-	-	-	-
2018		105	130	130	130	105	130	130
2019	Redesign	800	842	462	462	800	842	842
2020		877	821	455	455	877	821	821
2021		956	806	449	449	956	806	806
2022	Refresh	1,043	802	448	448	1,043	802	802
2023		1,123	793	442	442	1,123	793	793
2024	Redesign	1,365	1,117	572	572	1,364	1,118	1,118
2025		1,344	1,094	552	552	1,344	1,095	1,095
2026		1,323	1,071	531	531	1,323	1,072	1,072
2027	Refresh	1,380	1,420	589	589	1,379	1,420	1,420
2028		1,360	1,395	569	569	1,359	1,395	1,395
2029	Redesign	1,757	1,795	1,047	1,044	1,750	1,798	1,801
2030		1,733	1,766	1,022	1,019	1,726	1,769	1,772
2031		1,710	1,739	999	995	1,703	1,742	1,745
2032	Refresh	1,695	1,724	986	982	1,689	1,726	1,730
2033		1,693	1,722	984	981	1,687	1,724	1,728
2034	Redesign	1,692	1,720	497	980	1,685	1,722	1,726
2035		1,690	1,718	123	978	1,684	1,720	1,724
2036		1,688	1,716	(52)	977	1,682	1,718	1,722
2037	Refresh	1,686	1,714	(223)	975	1,680	1,716	1,720
2038		1,685	1,712	(390)	973	1,678	1,714	1,718
2039	Redesign	1,683	1,710	(554)	1,814	1,676	1,712	1,716
2040		1,681	1,708	(664)	1,669	1,675	1,710	1,714

2041		1,679	1,706	(772)	1,526	1,673	1,708	1,712
2042	Refresh	1,677	1,704	(878)	1,385	1,671	1,707	1,710
2043		1,676	1,702	(983)	1,246	1,669	1,705	1,708
2044	Redesign	1,674	1,700	(1,077)	1,119	1,668	1,703	1,706
2045		1,672	1,698	(1,088)	1,102	1,666	1,701	1,704
2046	Refresh	1,670	1,696	(1,100)	1,085	1,664	1,699	1,702
2047		1,669	1,695	(1,111)	1,068	1,663	1,697	1,700
2048		1,667	1,693	(1,123)	1,051	1,661	1,695	1,698
2049	Redesign	1,665	1,691	(1,134)	1,034	1,659	1,693	1,696
2050		1,663	1,689	(1,146)	1,018	1,657	1,691	1,694

As mentioned above, by making sufficient improvements to other vehicle models, Toyota could refrain from making the conventional RAV4s meet their CO_2 emissions targets. More broadly, Toyota can also use compliance credits to cover compliance gaps. The CAFE model accounts for the potential to transfer compliance credits between the passenger car (PC) and light truck (LT) fleets. The model also accounts for the potential to apply credits from prior model years (i.e., credits that have been "banked" or, equivalently, "carried forward"), including compliance credits earned prior to MY 2017. These aspects of the model interact with the model's accounting for multiyear planning—that is, the potential that a manufacturer, depending on its product design cadence and on the progression of standards, might apply "extra" technology in some model years in order to facilitate compliance in later model years. For example, if a manufacturer is only redesigning 15% of its fleet volume in MY 2025, that manufacturer might be best off—even setting aside credit banking—applying some "extra" technology (i.e., technology that leads to overcompliance) as part of vehicle redesigns planned for MYs 2018-2024, and carrying that technology forward into MY 2025 when there are fewer opportunities available to reduce CO_2 emissions in new models. As shown in Figure VI-62Figure VI-62, in Toyota's case, the model shows that Toyota could offset its light truck compliance gaps during MY 2017-2019 by applying compliance credits earned for light trucks prior to MY 2017. The graph also shows Toyota applying extra technology to its passenger car fleet during MYs 2018-2024 in order to comply with the MY 2025 passenger car standard, but also to carry forward compliance credits and use those credits to offset large compliance gaps for Toyota's light truck fleet during MYs 2023-2027. After MY 2025, the model shows the effects of some technology continuing to be inherited (especially during MYs 2026-2030) from prior MYs, of Toyota continuing to make voluntary improvements where economically attractive (like the MY 2034 and MY 2039 RAV4 EV mentioned above), and of Toyota continuing to transfer compliance credits from the passenger car to the light truck fleet.[1597]

[1597] While the fleets (PC and LT) are shown separately for compliance purposes in this example, the ability to utilize credits from either fleet toward total model year compliance (in the current year, without caps or limits) means that the fleets for a manufacturer comply jointly in each model year.

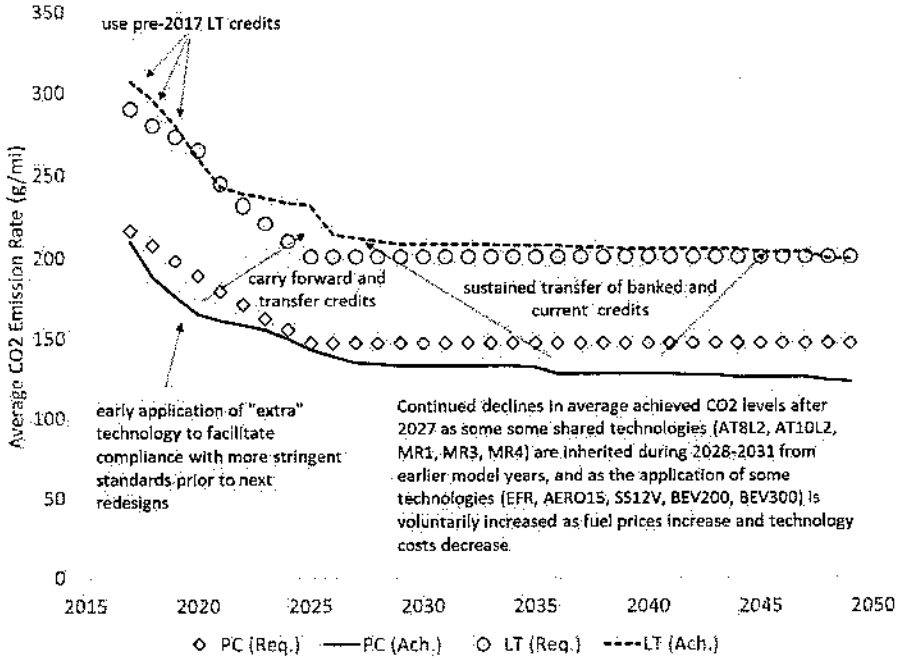

Figure VI-62 – Estimated CO_2 Requirements and Average Emission Rates for Toyota under Baseline CO_2 Standards

As the above figure shows, credit banking and transfers play an important role in Toyota's simulated response to the standards. If exercised in a manner that sets aside credit banking, the CAFE model shows Toyota increasing its application of fuel-saving technologies through MY 2025, and carrying those improvements forward, such that Toyota's overall average CO_2 emission rate is 15 g/mi lower in MY 2025 when credit banking is not accounted for. Though not shown here, accounting for credit banking also impacts the simulation other OEMs' compliance pathways, because inputs to today's analysis assume that Toyota would likely not need to use all of its pre-2017 compliance credits before these credits expire in 2021, and that Toyota could therefore sell those older credits other manufacturers (e.g., FCA, VW). By accounting for credit banking, the CAFE model thereby avoids considerable potential understatement of future CO_2 emissions from light-duty vehicles.

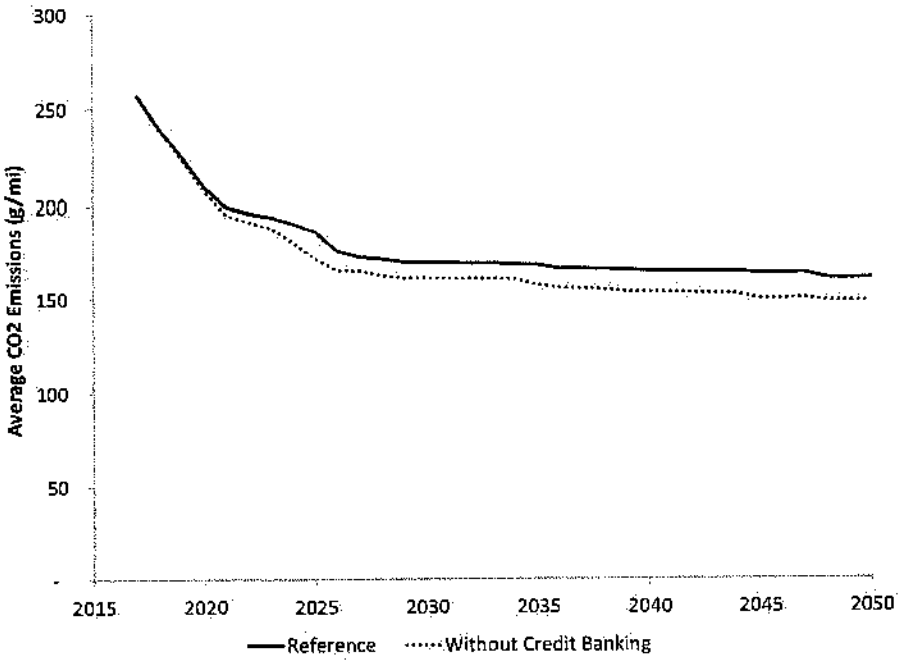

Figure VI-63 - Impact of Credit Banking on Estimated Toyota CO_2 Emission Rates under Baseline CO_2 Standards

As indicated by the following chart, a failure to account for credit banking would also increase Toyota's modeled per-vehicle costs by nearly $800 in MY 2025. By accounting for credit banking, the CAFE model thus avoids considerable potential overstatement of compliance costs. Though not shown here, accounting for credit banking while also applying inputs that reflect Toyota's ability to sell older credits to some other OEMs also enables the CAFE model to avoid overstatement of compliance costs for those OEMs.

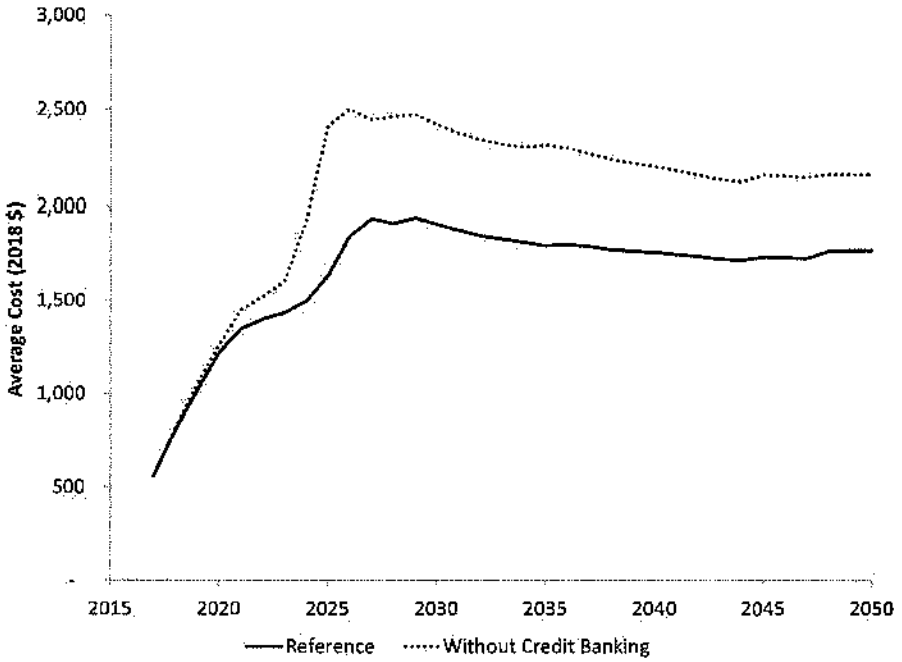

Figure VI-64 - Impact of Credit Banking on Estimated Toyota Per-Vehicle Costs under Baseline CO_2 Standards

While the model's simulation of manufacturers' potential responses to CAFE standards applies the same inputs and analytical methods, it does so accounting for several important statutory and regulatory differences between CO_2 standards and CAFE standards, and for specific statutory direction regarding how CAFE standards are to be considered for purposes of setting standards at the maximum feasible levels in each model year. EPCA places specific limits on the amount of credit that can be transferred between fleets, and requires that domestic passenger cars meet minimum standards without applying credits. EPCA also requires that the determination of maximum feasible stringency set aside the potential to apply compliance credits or introduce new alternative fuel vehicles (include BEVs and FCVs, but not including plug-in HEVs) during the model years under consideration. Especially with standards that continue to become more stringent, applying these statutory constraints to the analysis leads the model to tend to show greater overcompliance with standards in earlier model years, because even setting aside the potential to carry forward or transfer credits, Toyota is likely to find it more practicable to apply some "extra" technology when redesigning vehicles during MYs 2017-2024 than to attempt to address MY 2025 standards by working with only vehicles scheduled to be redesigned in MY 2025. The model also tends to show greater overcompliance in later model years, because some of that extra technology from years leading up to the last year of stringency

increases takes time to carry forward to ensuing model years. These aspects of the CAFE "standard setting" analysis are evident in the model's solution for Toyota, shown in the following figure. With the use of credits set aside after MY 2020, Toyota overcomplies with light truck standards during MYs 2018-2023 in order to carry technology forward into MY 2025. Although Toyota only marginally overcomplies with MY 2025 standards, the inheritance of technology during MYs 2026-2029 contributes to increased overcompliance, especially with the passenger car standards (which is to be expected given the degree of platform and powertrain sharing between the fleets). Continued increases in overcompliance after 2030 arise due to cost learning effects (especially for batteries) and increased fuel prices.

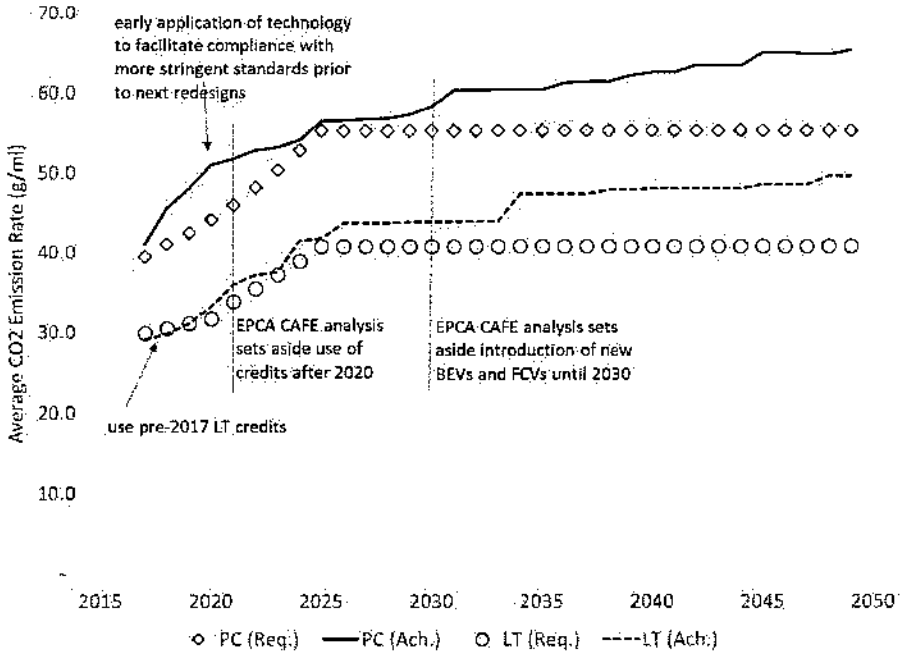

Figure VI-65 - Estimated CAFE Requirements and Levels for Toyota under Baseline CAFE Standards

VII. [Text Forthcoming]

VIII. [Text Forthcoming]

IX. Compliance and enforcement

A. Introduction

1. Overview

The CAFE and CO_2 emissions standards are both fleet-average standards, and for both programs, determining compliance begins by testing vehicles on dynamometers in a laboratory over pre-defined test cycles under controlled conditions.[1598] A machine is connected to the vehicle's tailpipe while it performs the test cycle, which collects and analyzes the resulting exhaust gases; a vehicle (such as a battery electric vehicle) that has no tailpipe emissions has its performance measured differently, as discussed below. CO_2 quantities, as one of the exhaust gases, can be evaluated for vehicles that produce CO_2 emissions directly. Fuel economy is determined from the amount of CO_2 emissions, because the two are directly mathematically related.[1599] Manufacturers generally perform their own testing, and EPA confirms and validates those results by testing a sample of vehicles at the National Vehicle and Fuel Emissions Laboratory (NVFEL) in Ann Arbor, Michigan. The results of this testing, along with flexibilities as discussed below, form the basis for determining a manufacturer's compliance in a given model year, through the following steps:

Commented [A415]: REVISE: Comments in this Compliance section IX are to correct/clarify EPA's GHG program descriptions, and include the placeholder text for the NGV multiplier.

- Each vehicle model's performance on the test cycles is calculated;
- The number of vehicles of that model that were produced is divided by the performance;
- That number, in turn is summed for all the manufacturer's model types;
- The manufacturer's total product volume is then divided by the summed value of all the model types; and

[1598] For readers unfamiliar with this process, it is similar to running a car on a treadmill following a program—or more specifically, two programs. 49 U.S.C. 32904(c) states that, in testing for fuel economy, EPA must "use the same procedures for passenger automobiles [that EPA] used for model year 1975 (weighted 55 percent urban cycle and 45 percent highway cycle), or procedures that give comparable results." Thus, the "programs" are the "urban cycle," or Federal Test Procedure (abbreviated as "FTP") and the "highway cycle," or Highway Fuel Economy Test (abbreviated as "HFET"), and they have not changed substantively since 1975. Each cycle is a designated speed trace (of vehicle speed versus time) that vehicles must follow during testing—the FTP is meant roughly to simulate stop and go city driving, and the HFET is meant roughly to simulate steady flowing highway driving at about 50 mph. The 2-cycle dynamometer test results differ ~~somewhat~~ considerably from what consumers will experience in the real world driving environment because ~~of~~ the 2-cycle tests lack ~~of~~ high speeds, rapid accelerations, ~~and hot and~~ cold temperatures, and hot temperature evaluations with the A/C operation. These added conditions, which reflect on average 20% lower fuel economy and 25% higher GHG emissions, are ~~more or~~ reflected in the EPA 5-cycle test results listed on each vehicle's fuel economy label and on the fueleconomy.gov website.

[1599] Technically, for the CAFE program, carbon-based tailpipe emissions (including CO_2, HC CH_4, and CO) are measured, and fuel economy is calculated using a carbon balance equation. EPA uses carbon-based emissions (CO_2, HC CH_4, and CO, the same as for CAFE) to calculate the tailpipe CO_2 equivalent for the tailpipe portion of its standards.

- That number represents the manufacturer's fleet harmonic average performance.

That performance is then compared to the manufacturer's unique compliance obligation (standard). This compliance obligation is calculated using the same approach that is used to determine performance, except that the fuel economy or CO_2 target value (based on the footprint of each vehicle model) is used instead of the model's measured performance value. The fuel economy or CO_2 target values for each of the vehicle models in the manufacturer's fleet and production volumes are used to derive the manufacturer's fleet ~~harmonic~~ average standard (for fuel economy, this is a harmonic average). Using fuel economy targets to illustrate the concept, the following figure shows two vehicle models produced in a model year for which passenger cars are subject to a fuel economy target function that extends from about 30 mpg for the largest cars to about 41 mpg for the smallest cars:

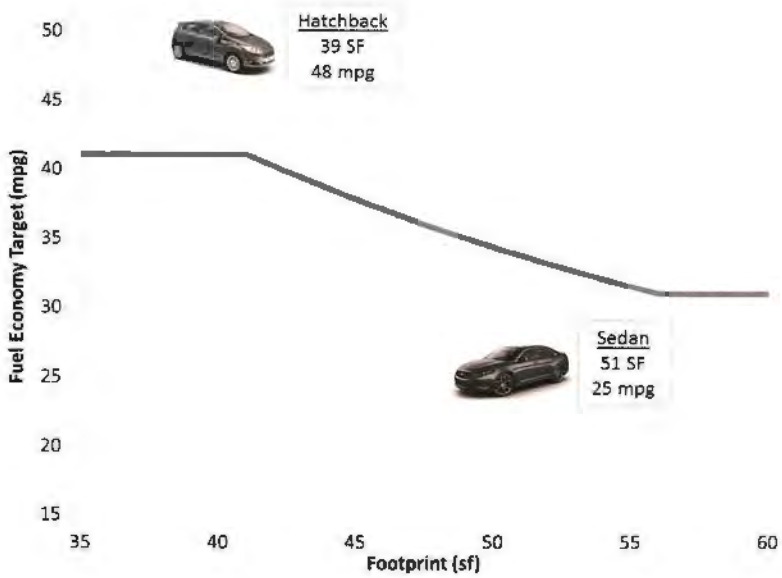

Figure 0-1 - Illustration of Vehicle Models vs. Fuel Economy Targets

If these are the only two vehicle models the manufacturer produces, the manufacturer's required CAFE obligation is determined by calculating the production-weighted harmonic average of the fuel economy target values applicable at the hatchback and sedan footprints (from the curve, about 41 mpg for the hatchback and about 33 mpg for the sedan). The manufacturer's achieved CAFE level is determined by calculating the production-weighted harmonic average of the hatchback and sedan fuel economy levels (in this example the values shown in the boxes in Figure 0-1Figure 0-1, 48 mpg for the hatchback and 25 mpg for the sedan). Depending on the

relative mix of hatchbacks and sedans the manufacturer produces, the manufacturer's fleet may meet the standard, ~~or~~ perform better than the standard (if required CAFE is less than achieved CAFE) and thereby earn credits, or perform worse than the standard (if required CAFE is greater than achieved CAFE) and thereby have a shortfall that may be made up, in whole or in part, using CAFE credits, discussed below, or be subject to civil penalties. Although the arithmetic is different for CO_2 standards (which do not involve harmonic averaging), the underlying concept is the same.

There are thus two parts to the foundation of compliance with CAFE and CO_2 emissions standards: first, how well any given vehicle model performs relative to its target, and second, how many of each vehicle model a manufacturer produces. While no given model need precisely meet its target (and virtually no model exactly meets its target in the real-world), if a manufacturer finds itself producing large numbers of vehicles that fall well short of their targets, it will have to find a way of offsetting that shortfall, either by increasing production of vehicles that exceed their targets, or by taking advantage of compliance flexibilities and incentives, or, for the CAFE program, the manufacturer will be subject to civil penalties. ~~Given that manufacturers typically need to produce for sale vehicles that consumers want to buy, and not all consumers value fuel economy, their options for pursuing the former approach can often be limited.~~

The CAFE and CO_2 programs both offer a number of compliance flexibilities and incentives, discussed in more detail below. For example, starting in model year 2017, manufactures have flexibility to account for efficiency improvements in air conditioning (A/C) systems and/or for the application fuel economy improving technologies that increase fuel economy in the real-world, but that are~~, in whole or in part,~~ not adequately accounted for (e.g., stop-start technology, or high efficiency alternators) using the 1975-based 2-cycle compliance dynamometer test procedures.[1600] These fuel economy improvements are added to the 2-cycle performance results and are included in the calculation of a manufacturer's fuel economy in determining compliance relative to standards. In addition, for MYs 2017 – 2025, there are also two levels of compliance incentives for full-size pickup trucks with mild-HEV or strong-HEV technology or that overperform standards by 15 percent or more, or by 20 percent or more.[1601] These fuel economy improvements are also included in the calculation of a manufacturer's fuel economy.[1602]

Some flexibilities and incentives are expressly provided for by statute for the CAFE program, and ~~some~~ others have been implemented by the agencies through regulations, consistent with the ~~statutory scheme~~agencies' respective statutes. Compliance flexibilities and incentives for the CAFE and CO_2 programs have ~~a great deal of theoretical attractiveness~~many merits: if designed properly, they can help to reduce overall regulatory costs, while maintaining

Commented [A416]: DELETE: EPA suggests deleting, as its not clear what is meant by "their options for pursuing the former approach can often be limited" – if this is referring to "increasing production of vehicles that exceed their targets" then this seems more of a technology feasibility claim, which is better placed in the Feasibility discussion, not a background section on how the compliance program works. Further, EPA does not agree with the statement "not all consumers value fuel economy" – if retained in some form, we suggest a more accurate description would be "different consumers value fuel economy differently."

[1600] EPA regulations provided an equivalent program beginning in MY 2012.

[1601] Manufacturers also must apply the technology to a minimum percentage of their full-size pickup truck production.

[1602] NHTSA characterizes any programmatic benefit manufacturers can use to comply with CAFE standards that fully accounts for fuel use as a "flexibility" (e.g., credit trading) and any benefit that counts less than the full fuel use as an "incentive" (e.g., adjustment of alternative fuel vehicle fuel economy). NHTSA flexibilities and incentives are discussed further in Section 9.D.

or improving environmental or energy ~~programmatic~~ benefits. If designed poorly, they may create significant potential for market distortion (for instance, ~~when~~if manufacturers—in response to an incentive to deploy a particular type of technology—produce vehicles for which there is ~~no natural market~~low consumer dmand, such vehicles might need to ~~must~~ be discounted in order to sell~~).~~[1602] ~~Manufacturers' use of compliance flexibilities and incentives requires proper governmental and industry collaboration for manufacturers to achieve the most effective pathways to compliance.~~[1603] ~~Overly complicated flexibility and incentive programs can result in greater expenditure of both private sector and government resources to track, account for, and manage. Moreover, flexibilities or incentives that tend to favor specific technologies could distort the market. By these means, compliance flexibilities or incentives could create an environment in which entities are encouraged to invest in such favored technologies and, unless those technologies are independently supported by market forces, encourage rent-seeking in order to protect, preserve, and enhance profits of companies that seek to take advantage of the distortions created by government mandate. Further, to the extent that there is a market demand for vehicles with lower CO_2 emissions and higher fuel economy, compliance flexibilities and incentives may cause some manufacturers to fall behind the industry's pace if they become overly reliant on them rather than simply improving the efficiency of their vehicles to meet that market demand.~~

If CAFE standards are maximum feasible levels, as required by the EPCA statute, then the need for extensive compliance flexibilities and incentives should be low. The agencies sought comments in the NPRM on whether and how each agency's existing flexibilities and incentives might be amended, revised, or deleted ~~to avoid the inefficiencies and market distortions discussed above~~. Specifically, NHTSA sought comments ~~were sought~~ on the appropriate level of compliance flexibility, including credit trading, in a program that is correctly designed to be maximum feasible, in accordance with the CAFE statute. Comments were also sought on whether to allow *all* incentive-based adjustments, except those that are mandated by the CAFE statute, to expire, in addition to other possible simplifications ~~to reduce market distortion.~~ improve program transparency and accountability, and improve overall performance of the compliance programs. The agencies considered comments on those issues in preparing the final rule. A summary of all the flexibilities for the CAFE and CO_2 programs finalized as a part of this final rule is provided in Table 0-1Table 0-1 though Table 0-4Table 0-4.

Commented [A417]: REVISE: EPA does not agree with this characterization of flexibilities in the context of both the EPA light-duty vehicle GHG program, and more broadly the many regulatory programs EPA has established under CAA Title II for motor vehicles and engines, and thus we suggest deleting this text.

Commented [A418]: REVISE: In this footnote, it is not clear what is the new information NHTSA is asking mfrs to provide on AC and off-cycle – suggest adding a cross-reference to preamble/regs where this is discussed.

Commented [A419]: REVISE: This sentence and the paragraph below are specific to the CAFE program, yet the paragraph in a number of places does not make this clear. The EPA suggested edits are to make it clear what program (CAFE or GHG) the sentences in this paragraph discuss.

~~[1602] While many manufacturers publicly discuss their commitment to certain technologies that reduce CO_2 emissions, consumer interest in them thus far remains low, despite often large financial incentives from both manufacturers and the Federal and State governments in the form of tax credits (i.e., natural gas or fuel-cell vehicles). It is questionable whether continuing to provide significant compliance incentives for technologies that consumers appear not to want is an efficient means to achieve either compliance or national goals (see, e.g., Congress' phase-out of the AMLA dual-fueled vehicle incentive in EISA, 49 U.S.C. 32906).~~

~~[1603] For these reasons, in this final rule, NHTSA is asking manufacturers to provide more detailed information on the new incentives allowed for A/C and off-cycle technologies and on credit trades for better collaboration in understanding the economic impact of these flexibilities and incentives and for the government to provide better oversight of the CAFE program.~~

Table 0-1 - Statutory flexibilities for over-compliance with standards

Regulatory item	NHTSA			EPA		
	Authority	Current Program	Final Rule	Authority	Current Program	Final Rule
Credit Earning	49 U.S.C. 32903(a)	Yes, denominated in tenths of a mpg	No change	CAA 202(a)	Yes, denominated in g/mi	No change
Credit "Carry-forward"	49 U.S.C. 32903(a)(2)	5 MYs into the future	No change	CAA 202(a)	5 MYs into the future (except MYs 2010-2015 = credits may be carried forward through MY 2021)	No change
Credit "Carryback" (AKA "deficit carry-forward")	49 U.S.C. 32903(a)(1)	3 MYs into the past	No change	CAA 202(a)	3 MYs into the past	No change
Credit Transfer	49 U.S.C. 32903(g)	Up to 2 mpg per fleet; transferred credits may not be used to meet min DPC standard	No change; Alliance/Global request to reconsider prior interpretation is denied	CAA 202(a)	Unlimited	No change
Credit Trade	49 U.S.C. 32903(f)	Unlimited quantity; traded credits may not be used to meet min DPC standard	No change	CAA 202(a)	Unlimited	No change

Table 0-2 - Flexibilities that address gaps in compliance test procedures

Regulatory item	NHTSA			EPA		
	Authority	Current Program	Final Rule	Authority	Current Program	Final Rule
A/C efficiency	49 U.S.C. 32904	Allows mfrs to earn "fuel consumption improvement values" (FCIVs) equivalent to EPA credits starting in MY 2017	No change, except to add advanced A/C compressor technology to the pre-approved menu; (Alliance/ Global request to allow retroactive starting in MY 2012 is denied)	CAA 202(a)	"Credits" for A/C efficiency improvements up to caps of 5.0 g/mi for cars and 7.2 g/mi for trucks	No change, except to add advanced A/C compressor technology to the pre-approved menu.
Off-cycle	49 U.S.C. 32904	Allows mfrs to earn "fuel consumption improvement values" (FCIVs) equivalent to EPA credits starting in MY 2017	No change, except to add high efficiency alternators to the pre-approved menu; (Alliance/ Global request to allow retroactive starting in MY 2012 is denied)	CAA 202(a)	"Menu" of pre-approved credits (~10 technologies), up to cap of 10 g/mi for MY 2014 and beyond; other pathways require EPA approval through either 5-cycle testing or through public notice and comment	No change, except to add high efficiency alternators to the pre-approved menu.

Table 0-3 - Incentives that encourage application of technologies

Regulatory item	NHTSA			EPA		
	Authority	Current Program	Final Rule	Authority	Current Program	Final Rule
Full-size pickup trucks with HEV or overperforming target	49 U.S.C. 32904	Allows mfrs to earn FCIVs equivalent to EPA credits starting in MY 2017 and ending in MY 2025	No change	CAA 202(a)	10 g/mi for full-size pickups with mild hybrids OR overperforming target by 15% (MYs 2017-2021); 20 g/mi for full-size pickups with strong hybrids OR overperforming target by 20% (MYs 2017-2025)	No change

Table 0-4 - Incentives that encourage alternative fuel vehicles

Regulatory item	NHTSA			EPA		
	Authority	Current Program	Final Rule	Authority	Current Program	Final Rule
Dedicated alternative fuel vehicle	49 U.S.C. 32905(a) and (c)	Fuel economy calculated assuming gallon of liquid or gallon equivalent gaseous alt fuel = 0.15 gallons of gasoline; for EVs petroleum equivalency factor	No change	CAA 202(a)	Multiplier incentives for EVs and FCVs (each vehicle counts as 2.0/1.75/1.5 vehicles in 2017-2021), NGVs (1.6/1.45/1.3 vehicles); each EV = 0 g/mi upstream emissions through MY 2021 (then phases out based on per-mfr production cap of 200k vehicles)	Multiplier of 2.0 added for MY 2022-2026 NGVs. No change to multipliers that phase out after MY 2021. Electricity usage = 0 g/mi extend through MY 2026.

Commented [A420]: CHANGE AS SHOWN: On this and following table, we added the NGV multiplier provision.

Dual-fueled vehicles	49 U.S.C. 32905(b), (d), and (e); 32906(a)	FE calc using 50% operation on alt fuel and 50% on gasoline through MY 2019. Starting with MY 2020, NHTSA will begin using the SAE defined "Utility Factor" methodology to account for actual potential use, and "F-factor" for FFV. NHTSA will continue to incorporate the 0.15 incentive factor.	No change	CAA 202(a)	Multiplier incentives for PHEVs and NGVs (each vehicle counts as 1.6/1.45/1.3 vehicles in 2017-2021); electric operation = 0 g/mi through MY 2021 (then phases out based on per-mfr production cap of 200k vehicles); "Utility Factor" method for use, and "F-factor" for FFV.	Multiplier of 2.0 added for dual-fuel NGVs. No change to multipliers that phase out after MY 2021. Electricity usage = 0 g/mi extend through MY 2026.
Connected/ Automated Vehicles	n/a	n/a	n/a	CAA 202(a)	Mfrs can petition for off-cycle credits	~~Denied~~No change.
High-octane fuel blends	n/a	n/a	n/a	CAA 202(a)	No incentives or requirements	No change

2. Light-Duty CAFE Compliance Data for MYs 2011-2019

To understand manufacturers' potential approaches to using compliance flexibilities and incentives, CAFE compliance data for MYs 2011 through 2019 is discussed in this section. NHTSA believes that providing these data is important because it gives the public a better understanding of current compliance trends and the potential impacts that increasing CAFE standards have had on those model years and future model years addressed by this rulemaking.

NHTSA uses data from CAFE reports submitted by manufacturers to EPA or directly to NHTSA to evaluate compliance with the CAFE program. The data for MYs 2011 through 2017

include manufacturers' final compliance data that have been verified by EPA.[1605] The data for MYs 2018 and 2019 include the most recent projections from manufacturers' mid-model year and final-model year reports submitted to EPA and NHTSA, as required by 49 CFR Part 537 and 40 CFR 600.512-12.[1606] Because the projections do not reflect final vehicle production levels, the EPA verified final CAFE values may be slightly different than the manufacturers' projections. MY 2011 was selected as the start of the data because it represents the first compliance model year for which manufacturers were permitted to trade and transfer credits.[1607] MY 2019 is also important because it shows the projected performance of the fleet two years after manufacturers were allowed to use new flexibilities and incentives starting in MY 2017 to address increasing CAFE standards.

Figure 0-2Figure 0-2 through Figure 0-5Figure 0-5 provide a graphical overview of fuel economy performance and standards. Fuel economy performance includes three parts: (1) measured performance, on the 2-cycle dynamometer test; (2) performance increases for alternative fueled vehicles, under the Alternative Motor Fuels Act of 1988 (AMFA); and (3) performance adjustments for improved A/C systems and off-cycle technologies.[1608,1609,1610] These Figures do not account for credits earned or expected to be earned from overcompliance in prior or future model years that were used or are available for complying with CAFE standards. Graphs are included for the total fuel economy performance (the combination of all passenger cars and light trucks produced for sale during the model year) as a single fleet, and for each of the three CAFE compliance fleets: domestic passenger car, import passenger car, and light truck fleets.

[1605] The data contain the latest information available from manufacturers except certain low volume manufacturers complying with standards under 49 CFR part 525.

[1606] MY 2018 data come from information received in manufacturers' final reports submitted to EPA according to 40 CFR 600.512-12 and MY 2019 data come from information received in manufacturers' mid-model year CAFE reports submitted to NHTSA according to 49 CFR part 537.

[1607] 49 CFR 535.6(c).

[1608] In the Figures, the label "CAFE with Capped AMFA" represents the maximum increase each year in the average fuel economy set to the limitation "cap" for manufacturers attributable to dual-fueled automobiles as prescribed in 49 U.S.C. 32906. The labels "A/C" and "off-cycle" represent the increase in the average fuel economy adjusted for A/C and off-cycle fuel consumption improvement values as prescribed by 40 CFR 600.510-12.

[1609] The Alternative Motor Fuels Act (AMFA) allows manufacturers to increase their fleet fuel economy performance values by producing dual-fueled vehicles. Incentives are available for building advanced technology vehicles such as hybrids and electric vehicles, compressed natural gas vehicles and for building vehicles able to run on dual-fuels such as E85 and gasoline. For MYs 1993 through 2014, the maximum possible increase in CAFE performance is "capped" for a manufacturer attributable to dual-fueled vehicles at 1.2 miles per gallon for each model year and thereafter decreases by 0.2 miles per gallon each model year through MY 2019. 49 U.S.C. 32906.

[1610] Consistent with applicable law, NHTSA established provisions starting in MY 2017 allowing manufacturers to increase fuel economy performance-based on fuel consumption benefits gained by technologies not accounted for during normal 2-cycle EPA compliance testing (called "off-cycle technologies" for technologies such as stop-start systems) as well as for A/C systems with improved efficiencies and for hybrid or electric full-size pickup trucks.

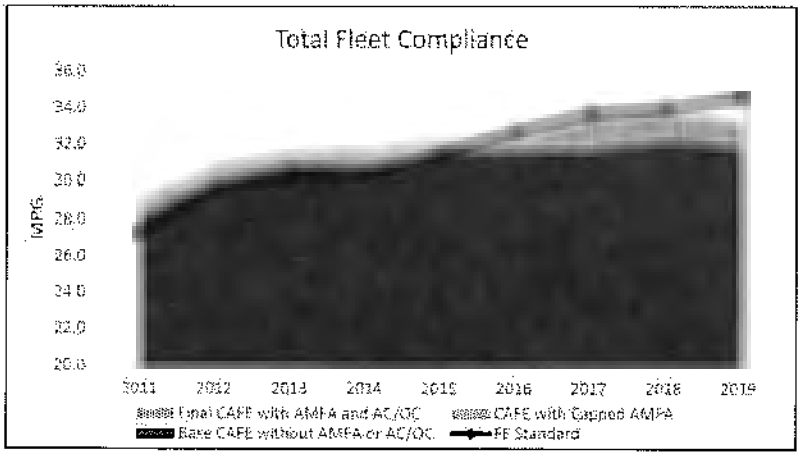

Figure 0-2 - Total Fleet Compliance Overview for MYs 2011 to 2019

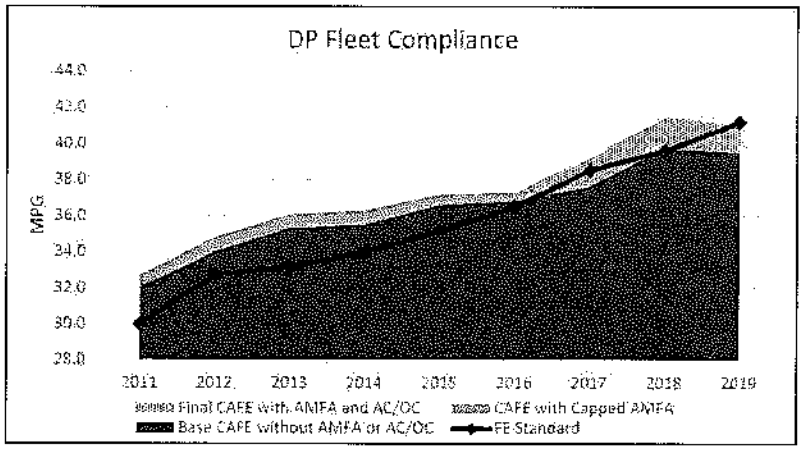

Figure 0-3 - Domestic Passenger Car Compliance Overview for MYs 2011 to 2019

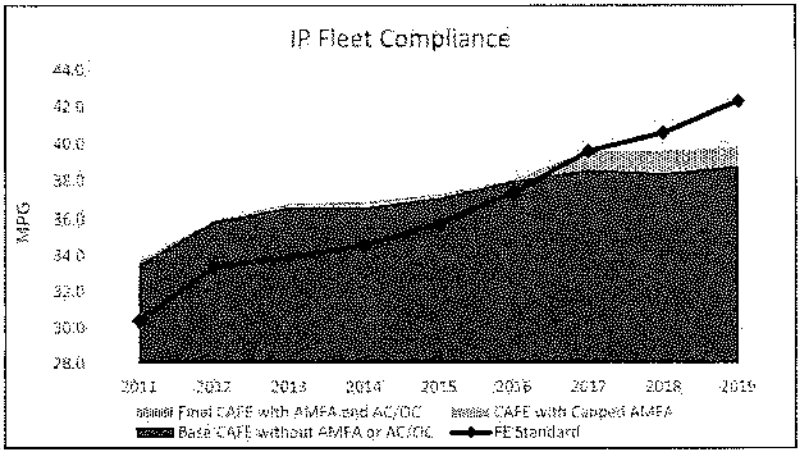

Figure 0-4 - Import Passenger Car Compliance Overview for MYs 2011 to 2019

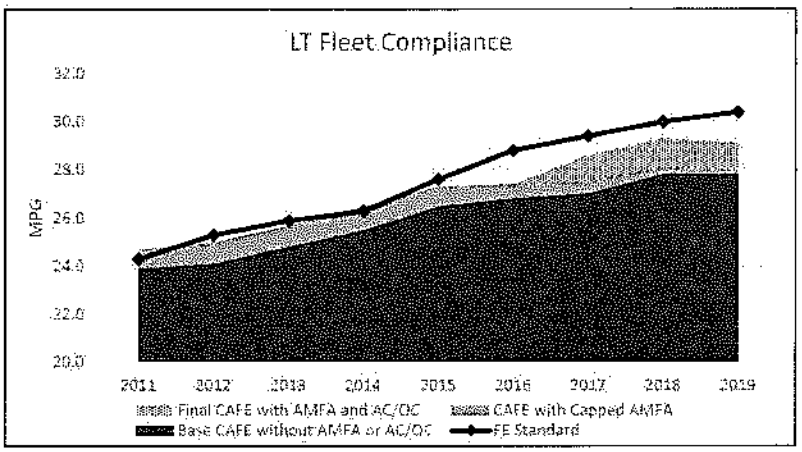

Figure 0-5 - Light Truck Compliance Overview for MYs 2011 to 2019

As shown in Figure I-2, manufacturers' fuel economy performance for the total fleet was better than the overall CAFE standard through MY 2015. On average, the total fleet exceeded the overall CAFE standards by approximately 0.9 mpg for MYs 2011 to 2015. Comparatively, as shown in Figure I-3 through I-5, for these same model years, domestic and import passenger cars exceeded standards on average by 2.1 mpg and 2.3 mpg, respectively. By contrast, for light trucks, manufacturers on average fell below standards by 0.3 mpg.

For MYs 2016 through 2019, as shown in the Figures, NHTSA has determined that the combined CAFE performance, including all flexibilities and incentives, of the total fleet has or is expected to be worse than the applicable CAFE standards, and increasingly so. The domestic passenger car fleet is the only compliance category expected to continue to be better than CAFE standards through MY 2018. But even the overall domestic passenger car fleet is expected to be worse than standards in MY 2019. The data show MYs 2016 through 2019 standards involve significant compliance challenges for many vehicle manufacturers. This is evident in the fact that the total fleet falls below the applicable CAFE standards on average by 0.6 mpg for these model years. Compliance challenges become even more substantial when observing individual compliance fleets. The largest individual performance shortfalls (i.e. the difference between CAFE performance values and standards) exist for import passenger car manufacturers, with an expected shortfall of 2.5 mpg in MY 2019, followed by light truck manufacturers, with a shortfall of 1.4 mpg in MY 2016.

Table 0-5Table 0-5**Error! Reference source not found.** provides the numerical final CAFE performance values and standards for MYs 2004 to 2017. Notably, there was an increase in total fleet fuel economy of only 0.1 mpg for MY 2014, and no increase for MY 2016. In MY 2016, the total fleet's performance fell below the CAFE standard by 0.5 mpg. An increase in the total fleet's CAFE performance for MY 2017 was largely due to manufacturers gaining benefits from A/C and off-cycle technologies. For MY 2017, the total fleet's CAFE performance without A/C and off-cycle allowances increased by 0.1 mpg compared to MY 2016. However, even combined with new flexibilities, the total fleet's CAFE performance, for MY 2017, still falls below the CAFE standard by 0.4 mpg.

Table 0-5 - CAFE Performance and Standards for MYs 2004 to 2017

Model Year	Domestic Passenger Car		Import Passenger Car		Light Truck		Total Fleet	
	CAFE (mpg)	Standard (mpg)	CAFE (mpg)	Standard (mpg)	CAFE (mpg)	Standard (mpg)	CAFE (mpg)	Standard (mpg)
2017	39.2	38.5	39.6	39.6	28.6	29.4	33.4	33.8
2016	37.3	36.5	38.2	37.4	27.4	28.8	32.2	32.7
2015	37.2	35.2	37.3	35.8	27.3	27.6	32.2	31.6
2014	36.3	34.0	36.9	34.6	26.5	26.3	31.7	30.5
2013	36.1	33.2	36.8	33.9	25.7	25.9	31.6	30.3
2012	34.8	32.7	36.0	33.4	25.0	25.3	30.8	29.8
2011	32.7	30.0	33.7	30.4	24.7	24.3	29.0	27.4
2010	33.1	27.5	35.2	27.5	25.2	23.4	29.3	25.4
2009	32.1	27.5	33.8	27.5	24.8	23.0	29.0	25.4
2008	31.2	27.5	31.8	27.5	23.6	22.4	27.1	24.7
2007	30.6	27.5	32.2	27.5	23.1	22.2	26.6	24.6
2006	30.3	27.5	29.7	27.5	22.5	21.6	25.8	24.2
2005	30.5	27.5	29.9	27.5	22.1	21.0	25.4	23.7
2004	29.9	27.5	28.7	27.5	21.5	20.7	24.6	23.4

Figure 0-6Figure 0-6 provides a historical overview of the industry's use of CAFE compliance flexibilities for addressing performance shortfalls.[1611] MY 2016 is the latest model year for which CAFE compliance determinations are complete, and credit application and civil penalty payment determinations made by the manufacturer. Historically, manufacturers have generally resolved credit shortfalls first by carrying forward any earned credits and then applying traded credits. In MYs 2014 and 2015, the amount of credit shortfalls is almost the same as the amount of carry-forward and traded credits. Manufacturers occasionally carryback credits or opt to transfer earned credits between their fleets to resolve performance shortfalls. Trading credits from another manufacturer and transferring them across fleets occurs far more frequently. Also, credit trading has generally taken the place of civil penalty payments for resolving performance shortfalls. Only a handful of manufacturers have made civil penalty payments since the implementation of the credit trading program.[1612] NHTSA expects there may be sufficient credits in manufacturers' credit accounts to resolve all import passenger car and light truck performance shortfalls expected through MY 2019. By statute, manufacturers cannot use traded or transferred credits to address performance shortfalls for failing to meet the minimum domestic passenger car standards.[1613] One domestic passenger car manufacturer paid a civil penalty for failing to comply with the minimum domestic passenger car standard for MY 2016.[1614] Additional manufacturers are expected to pay civil penalty payments for failing to comply with the minimum domestic passenger cars standards for MYs 2017 through 2019.

[1611] The Figure includes all credits manufacturers have used in credit transactions to date. Credits contained in carryback plans yet to be executed or in pending enforcement actions are not included in the Figure.

[1612] Six manufacturers have paid CAFE civil penalties since credit trading began in 2011. Fiat Chrysler paid the largest civil penalty total over the period, followed by Jaguar Land Rover and then Volvo. *See* Summary of CAFE Civil Penalties Collected, CAFE Public Information Center, https://one.nhtsa.gov/cafe_pic/CAFE_PIC_Fines_LIVE.html.

[1613] Congress prescribed minimum domestic passenger car standards for domestic passenger car manufacturers and unique compliance requirements for these standards in 49 USC 32902(b)(4) and 32903(f)(2).

[1614] Fiat Chrysler paid $77,268,702.50 in civil penalties for failing to comply with the minimum domestic passenger car standard for MY 2016.

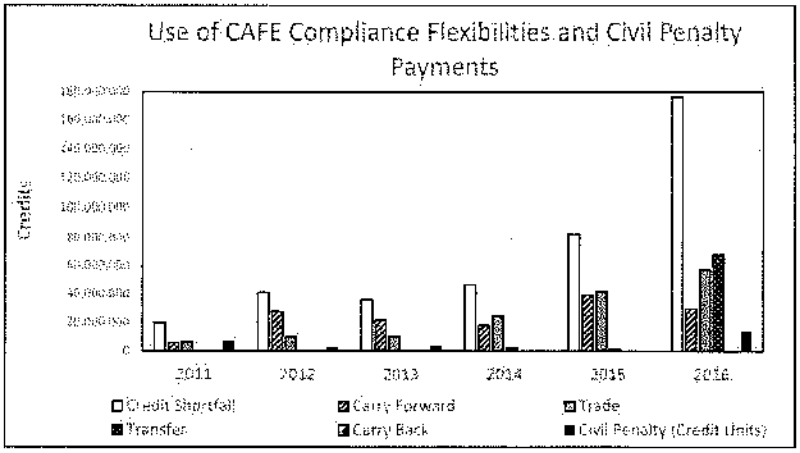

Figure 0-6 - Industry Use of Compliance Flexibilities and Civil Penalty Payments

The compliance data show that the rate at which industry has been increasing fuel economy, as shown by the actual fuel economy of the overall fleet, has not kept pace with the year-over-year increases in the stringency of the standards since MY 2010. The margin of CAFE overcompliance diminished steadily through MY 2015. In MY 2016, the fuel economy of the fleet was worse than standards, and the margin of the shortfall has or is projected to become worse through MY 2019. Manufacturers have increasingly used CAFE compliance flexibilities and paid more in civil penalties to address the growing CAFE shortfalls. The data show use of these flexibilities is likely to increase at least through 2019.

3. Shift in Sales Production from Passenger Cars to Light Trucks

The notable trend in the stagnant growth in the automotive industry's CAFE performance is likely related to an increase in the purchase of light trucks beginning with MY 2013. Light trucks had a sharp spike in sales, increasing by a total of 5 percent from MYs 2013 to 2014. In MY 2014, light trucks comprised approximately 41 percent of the total sales production volume of automobiles and has continued to grow ever since. In comparison, for model year 2014, domestic passenger cars represented 36 percent of the total fleet and import passenger cars represented 23 percent. Both domestic and import passenger car sales have continued to fall every year since MY 2013. Figure 0-7Figure 0-7 shows the sales production volumes of light trucks and domestic and import passenger cars for MYs 2004 to 2017. The proportion of light trucks in the fleet, being driven by consumer demand and lower fuel prices, raises some concern for the ability of that fleet to comply with future CAFE standards. Historically, light truck fleets have fallen below their associated CAFE standards and have had larger performance shortages than either import and domestic passenger car fleets. This trend is expected to continue, even with allowance for A/C and off-cycle flexibilities. For MY 2019, NHTSA expects even greater CAFE performance shortages in the light truck and import passenger car fleets than in prior model years, based upon manufacturer's MMY reports. The combined effect of these fuel

economy shortages will require manufacturers to rely heavily on compliance flexibilities or pay civil penalties.

Another important factor in automobile sales production impacting CAFE performance values involves increasing trends in the volume of siuall SUVs and pickup trucks. These vehicles as a percentage of total fleet increased from approximately 52 percent in MY 2012 to 63 percent in MY 2017. As shown in Figure 0-8Figure 0-8, small SUVs, with 4WD and 2WD drivetrains, in particular have surpassed the sales production volumes of all other vehicle classes over these the given model years. The number of small and standard SUVs sold in the U.S. for MY 2017 nearly doubled compared to sales in the U.S. for MY 2012. During that same period, passenger car sales production as a total of vehicle sales production decreased by approximately 11 percent. The combination of low gas prices and the increased utility that SUVs provide may explain the shift in sales production. Nonetheless, if the sales of these small SUVs and pickup trucks continue to increase, NHTSA expects there will be continued stagnation in the CAFE performance of the overall fleet.

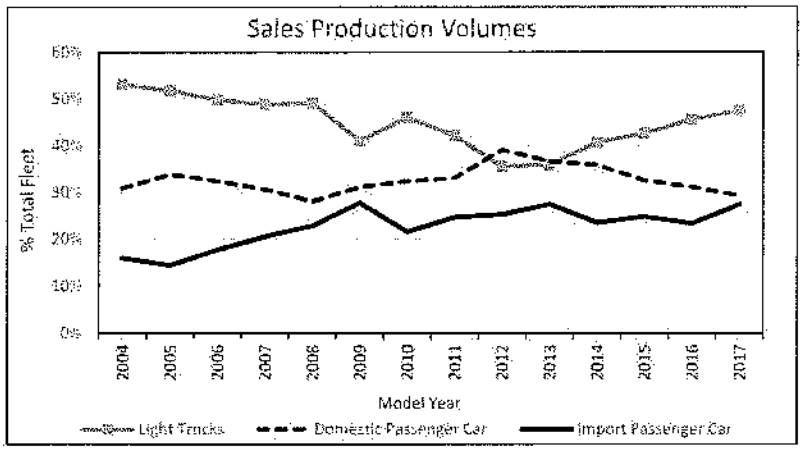

Figure 0-7 - Sales Production Volumes for MYs 2004 to 2017

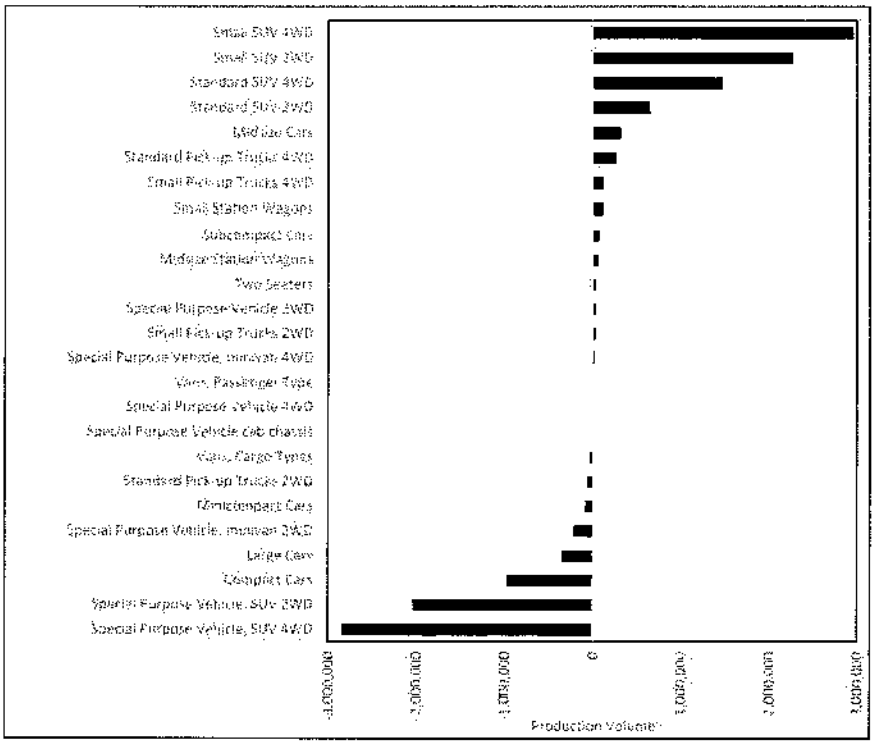

Figure 0-8 - Vehicle Class Production Changes for MYs 2012 to 2017

4. Vehicle Classification

Before manufactures can comply with CAFE and CO_2 standards, they must first determine how a vehicle is classified in accordance with 49 CFR Part 523, "Vehicle Classification." In EPCA, Congress designated some vehicles as passenger automobiles and some as non-passenger automobiles. Vehicle classification, for purposes of the light-duty CAFE and CO_2 programs, refers to whether a vehicle is classified as a passenger automobile (car) or a non-passenger automobile (light truck).[1615, 1616] As discussed previously, passenger cars and

[1615] *See* 40 CFR 86.1803-01. For the MYs 2012–2016 standards, the MYs 2017–2025 standards, and this rule, EPA uses NHTSA's regulatory definitions for determining which vehicles would be subject to which CO_2 standards.
[1616] EPCA uses the terms "passenger automobile" and "non-passenger automobile;" NHTSA's regulation on vehicle classification, 49 CFR part 523, further clarifies the EPCA definitions and introduces the term "light truck" as a plainer language alternative for "non-passenger automobile."

light trucks are subject to different fuel economy and CO_2 standards, and light trucks have less stringent standards to accommodate their utility usage.

Under EPCA and NHTSA's current regulations, vehicles are classified as light trucks either on the basis of off-highway capability or on the basis of having truck-like (utility) characteristics.[1617, 1618, 1619] Determining whether a vehicle is capable of "off-highway operation" is a two-part determination: first, does the vehicle either have 4-wheel drive or a gross vehicle weight rating (GVWR) over 6,000 pounds, and second, does the vehicle (that has either 4-wheel drive or over 6,000 pounds GVWR) also have "a significant feature … designed for off-highway operation."[1620] NHTSA's current regulations specify that this "significant feature" requires the vehicle to meet at least four out of five ground clearance dimensions.[1621] Further, to be classified as a light truck on the basis of having truck-like characteristics instead, NHTSA regulations also require the vehicle to perform at least one of the following functions: carry more than 10 persons, provide temporary living quarters, have an open bed (*i.e.*, a pickup truck), provide more cargo-carrying volume than passenger-carrying volume, or permit expanded cargo volume capacity by the removal or stowing of rear seats.[1622]

Over time, NHTSA has revised its light truck vehicle classification regulations and issued legal interpretations to address changes in vehicle designs. Based upon agency observations of current vehicle design trends, compliance testing and evaluation, and discussions with stakeholders, NHTSA has become aware of certain additional design changes that further complicate light truck classification determinations for the CAFE and CO_2 programs. NHTSA discussed several classification issues in the NPRM and sought comments on potential resolutions. Only a few comments were received, primarily from vehicle manufacturers, and they were aimed generally at requesting flexibility in how NHTSA applies the existing classification criteria. A summary of the comments received and NHTSA's responses for the final rule are explained in the following sections.

a. Classification Based on "Truck-Like Characteristics"

One of the "truck-like characteristics" that allows manufacturers to classify vehicles as light trucks is having at least three rows of seats as standard equipment, as long as the design also "permit[s] expanded use of the automobile for cargo-carrying purposes or other non-passenger-carrying purposes through the removal or stowing of foldable or pivoting seats so as to create a flat, leveled cargo surface extending from the forwardmost point of installation of those seats to the rear of the automobile's interior."[1623] Typically, most minivans qualify under the

[1617] 49 USC 32901(a)(18); 49 CFR part 523.
[1618] 49 CFR 523.5(b).
[1619] 49 CFR 523.5(a).
[1620] 49 U.S.C. 32901(a)(18).
[1621] The ground clearance dimensions are: (i) approach angle of not less than 28 degrees; (ii) breakover angle of not less than 14 degrees; (iii) departure angle of not less than 20 degrees; (iv) running clearance of not less than 20 centimeters; and/or (v) front and rear axle clearances of not less than 18 centimeters each.
[1622] By statute, vehicles that NHTSA, on behalf of the Secretary of DOT, "decides by regulation [are] manufactured primarily for transporting not more than 10 individuals" are passenger automobiles. 49 U.S.C. 32901(a)(18).
[1623] 49 CFR 523.5(a)(5)(ii).

provision by expanding the cargo area through removable or stowable seats, and a small percentage of sports utility vehicles qualify through folding seats that use the seat backs to form a secondary "raised" cargo floor.[1624] NHTSA identified two issues with this criterion that various manufacturers appear to be approaching differently. Both relate to how expanded cargo area is provided when seats are removed or stowed in the vehicle.

The first issue is how to identify the "forwardmost point of installation" and how the location impacts the available cargo floor area and volume behind the seats. Seating configurations have evolved considerably over the last twenty years, as minivan seats are now very complex in design, providing far more ergonomic functionality. For example, the market demand for increased rear seat leg room has resulted in adjustable second row seats mounted to sliding tracks. Earlier seating designs had fixed attachment points on the vehicle floor, and it was easy to identify the "forwardmost point of installation" because it was readily observable and did not change. When seats move forward and backward on sliding tracks, however, the "forwardmost point of installation" is less readily identifiable. To avoid this complication, most manufacturers maintain light truck qualification by using adjustable seats that can be removed from the vehicle and having a flat floor rearward of the front seats.[1625] For others, the qualification is not as apparent because new adjustable seats have been introduced that remain within vehicle to accommodate side airbags. Manufacturers designate various positions for the forwardmost point of installation in vehicles where the seat in the sliding track can be moved far enough forward to allow the entire seat to compress against the back of the front seat where it can be stowed beyond the forwardmost point of installation, while the seat cushion bottom folds towards the seatback. In some cases, manufacturers designate the forwardmost point of installation at a location in the sliding track where the seat is positioned at its *rearmost* position in the track. In others, the initial point of installation is designated at a location in the sliding track accommodating the seating position of a 75-percentile male test dummy. The amount of the flat floor surface area and cargo volume behind the seats can vary depending on which approach a manufacturer adopts.

NHTSA sought public comments in the NPRM to explore potential options for establishing the forwardmost point of installation for adjustable second row seats and to evaluate whether an additional classification criteria could be required, specifying a minimum amount of cargo volume behind the seats. Comments were received from the Auto Alliance and Fiat Chrysler.[1626] Both the Auto Alliance and Fiat Chrysler commented that some flexibility is needed in determining the forwardmost point of installation that allows manufacturers to set the location of the seat attachment point to the sliding track in any manufacturer-designated position that allows for customer-ergonomics and safety, while still meeting the spirit of the expanded

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[1624] All minivans and a small percentage of sports utility vehicles that qualify as light trucks do so by meeting the characteristic for third row seats. As more advanced seating designs are introduced in minivans, manufacturers that wish to retain this status will need to avoid losing the expanded cargo characteristics that are the basis for the allowing minivans to be qualified as light trucks.

[1625] NHTSA notes that to qualify as a light truck, a vehicle still requires a flat floor from the forwardmost point of installation of removable second row seats to the rear of the vehicle.

[1626] The National Automobile Dealers Association commented generally that it does not support any substantial modifications to the existing passenger car and light truck fleet definitions.

cargo-carrying requirement.[1627] The Auto Alliance further commented that the forwardmost attachment point of the seat structure to the floor is still a viable method of measurement, even when there is a sliding track between the floor attachment point and the seat.[1628]

NHTSA did not propose any vehicle reclassifications and is not adopting a regulatory change at this time. Based on its review of the comments, NHTSA agrees that flexibility is warranted to accommodate safety and customer demand but clarifies that the regulation requires seats that are not removed to be stowed—that is, moved so as to form a cargo area behind the seats. Manufacturers can freely designate the seating location in the sliding track to establish the forwardmost point of installation. At that seat location, the forwardmost point of installation is the forwardmost attachment point of the seat structure (including any carriage structures) to the floor in the sliding track. Vehicles will be considered to meet the characteristic provided the rear of the seats can be moved forward beyond that point and the seats articulate to an unusable stowed position either in the floor of the vehicle or at the front perimeter of expanded cargo area.[1629]

The second issue concerns the "flatness" and "levelness" of folded rear seats that use the seat backs to form a raised cargo surface and whether the seats must form a continuous flat, leveled surface. Many SUVs have three rows of designated seating positions, where the second row has "captain's seats" (*i.e.*, two independent bucket seats), rather than the traditional bench-style seating more common when the provision was added to NHTSA's regulation. When captain's seats are folded down, the seatback can form a flat surface for expanded cargo-carrying purposes, but the surface of the seatbacks may be angled (*i.e.*, at some angle slightly greater than 0°), or may be at a different level with the rest of the cargo area (*i.e.*, horizontal surface of folded seats is 0° at a different height from horizontal surface of cargo area behind the seats). Captain's seats, when folded flat, may also leave significant gaps around and between the seats. Some manufacturers have opted to use plastic panels to level the surface and to covers the gaps between seats, while others have left the space open and the surface angled or at different levels. NHTSA sought comments in the NPRM on the following questions related to the requirement for a flat, leveled cargo surface:

- Does the cargo surface need to be flat and level in exactly the same plane, or does it fulfill the intent of the criterion and provide appropriate cargo-carrying functionality for the cargo surface to be other than flat and level in the same plane?
- Does the cargo surface need to be flat and level across the entire surface, or are (potentially large) gaps in that surface consistent with the intent of the criterion and providing appropriate cargo-carrying functionality? Should panels to fill gaps be required?
- Certain third row seats are located on top the rear axle causing them to sit higher and closer to the vehicle roof. When these seats fold flat the available cargo-carrying

[1627] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1628] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1629] The front perimeter of the cargo area is the plane formed behind the front seats and extending from one side of the vehicle to the other.

volume is reduced. Is cargo-carrying functionality better ensured by setting a minimum amount of useable cargo-carrying volume in a vehicle when seats fold flat?

The Auto Alliance, Fiat Chrysler, Hyundai, Kia, and one individual, Walter Kreucher, commented on these seating issues. The Auto Alliance, Fiat Chrysler, and Walter Kreucher believed that the criteria for a "flat, leveled cargo surface" should not be interpreted to mean that a cargo surface must be flat and level in exactly the same plane.[1630] The comments noted that a surface that is not exactly flat and level in the same plane can still provide substantial cargo-carrying capacity, while allowing manufacturers to provide ergonomically comfortable seats that meet safety requirements.[1631] The comments stated that NHTSA should not establish a minimum amount of cargo surface area for seats that remain within the vehicle.[1632] Instead, they preferred that manufacturers should be allowed to determine the methodology for providing appropriate cargo-carrying functionality without NHTSA stipulating additional requirements for flat and level surfaces or gaps and gap-filling panels.[1633]

The Auto Alliance and Fiat Chrysler argued that area or volume requirements are not needed, as those attributes speak to overall vehicle size and shape, which should remain a consumer choice.[1634] The requirements for expanded cargo- or other non-passenger-carrying purposes are fully met in the existing regulation, which requires a flat, leveled cargo surface with two rows of seats that are folded or stowed. Fiat Chrysler also commented that potential new requirements would likely be interpreted and executed differently across manufacturers and could narrow the choice of engineering solutions and negatively affect other important vehicle attributes.[1635]

Hyundai and Kia commented that instead of requiring panels, NHTSA could limit the size of the gaps around and between folded seats.[1636] In that case, manufacturers would have flexibility to use panels if they wish but could take other measures to narrow gaps. On the other hand, Walter Kreucher stated that NHTSA should allow gaps of any size and not require the use of panels to cover them.[1637]

NHTSA is not adopting a regulatory change at this time. NHTSA agrees with commenters that it should not require a minimum amount of cargo surface area or volume for seats that remain within the vehicle, which could be difficult to meet for certain vehicle sizes and shapes that would otherwise be considered non-passenger vehicles. NHTSA agrees that the

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[1630] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Walter Kreucher, Detailed Comments, NHTSA-2018-0067-0444.
[1631] *See, e.g.*, Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1632] *See, e.g.*, Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1633] *See, e.g.*, Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1634] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1635] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1636] Hyundai, Detailed Comments, EPA-HQ-OAR-2018-0283-4411; Kia, Detailed Comments, EPA-HQ-OAR-2018-0283-4195.
[1637] Kreucher, Detailed Comments, NHTSA-2018-0067-0444.

amount of cargo volume should be a consumer choice. Setting a minimum amount of cargo area or volume could have an adverse effect on potential new car buyers.

NHTSA notes that there may also be safety considerations involved with the requirement to have a flat, leveled cargo surface area formed by seat backs. A flat, leveled cargo surface area could prevent objects from having a ramp-like surface to gain momentum in rolling backwards into the tailgate's interior surface, potentially causing stress or damage on the tailgate's latching mechanism. For these reasons, several standards exist in the industry for preventing objects from sliding, such as standards from the American Disability Act (ADA) that specify floor and ground design requirements for protecting wheelchair seated occupants. In addition, objects resting on the tailgate could become a hazard or source of injury for individuals opening the tailgate. At this time, NHTSA accepts the commenters' position that having a cargo surface area that is exactly flat and level in the same plane may not be necessary. Comments did not provide enough information for NHTSA to identify any changes to the existing requirements. Therefore, at this time, NHTSA will retain its existing provisions for the stowing of foldable or pivoting seats to create a flat, leveled cargo surface, but NHTSA may consider conducting research in the future regarding these issues. NHTSA has also determined that it should set not a limit on the size of the gaps between folded seats at this time, although it may consider adopting such limits in the future. NHTSA continues to encourage manufacturers to consider the safety implications of all aspects of their vehicle designs, including any angling of the seat back cargo surface and whether it is appropriate to offer panels as optional equipment for covering any large gap openings.

b. Issues that NHTSA has Observed Regarding Classification Based on "Off-Road Capability"

(1) Measuring Vehicle Characteristics for Off-Highway Capability

For a vehicle to qualify as off-highway capable, in addition to either having 4WD or a GVWR more than 6,000 pounds, the vehicle must have four out of five characteristics indicative of off-highway operation.[1638] These characteristics are:

- An approach angle of not less than 28 degrees
- A breakover angle of not less than 14 degrees
- A departure angle of not less than 20 degrees
- A running clearance of not less than 20 centimeters
- Front and rear axle clearances of not less than 18 centimeters each

NHTSA's regulations require manufacturers to measure these characteristics when a vehicle is at its curb weight, on a level surface, with the front wheels parallel to the automobile's longitudinal centerline, and the tires inflated to the manufacturer's recommended cold inflation pressure.[1639] Given that the regulations describe the vehicle's physical position and

[1638] 49 CFR 523.5(b)(2).
[1639] *Id.*

characteristics at time of measurement, NHTSA previously assumed that manufacturers would use physical measurements of vehicles. In practice, NHTSA has instead received from manufacturers a mixture of angles and dimensions from design models (*i.e.*, the vehicle as designed, not as actually produced) and/or physical vehicle measurements.[1640] When appropriate, the agency will verify reported values by measuring production vehicles in the field. NHTSA currently requires that manufacturers use physical vehicle measurements as the basis for values reported to the agency for purposes of vehicle classification. NHTSA sought comment on whether regulatory changes are needed with respect to this issue.

(2) Approach, Breakover, and Departure Angles

Approach angle, breakover angle, and departure angle are relevant to determining off-highway capability. Large approach and departure angles ensure the front and rear bumpers and valance panels have sufficient clearance for obstacle avoidance while driving off-road. The breakover angle ensures sufficient body clearance from rocks and other objects located between the front and rear wheels while traversing rough terrain. Both the approach and departure angles are derived from a line tangent to the front (or rear) tire static loaded radius arc extending from the ground near the center of the tire patch to the lowest contact point on the front or rear of the vehicle. The term "static loaded radius arc" is based upon the definitions in SAE J1100 and J1544. The term is defined as the distance from wheel axis of rotation to the supporting surface (ground) at a given load of the vehicle and stated inflation pressure of the tire (manufacturer's recommended cold inflation pressure).[1641]

The static loaded radius arc is easy to measure, but the imaginary line tangent to the static loaded radius arc is difficult to ascertain in the field. The approach and departure angles are the angles between the line tangent to the static loaded radius arc and the level ground on which the test vehicle rests. Simpler measurements that provide good approximations for the approach and departure angles involve using either a line tangent to the outside diameter or perimeter of the tire or a line that originates at the geometric center of the tire contact patch and extends to the lowest contact point on the front or rear of the vehicle. The first method provides an angle slightly greater than, and the second method provides an angle slightly less than, the angle derived from the true static loaded radius arc. Both approaches can be used to measure angles in the field to verify data submitted by the manufacturers used to determine light truck classification decisions.

NHTSA sought comment on what the effect would be if it replaced reference to the "static loaded arc radius" with a different term like "outside perimeter of the tire" or "geometric center of the tire contact patch." The Auto Alliance and Fiat Chrysler offered comments. The Auto Alliance and Fiat Chrysler commented that only a measurement using the static loaded arc radius reasonably reflects the tire condition during off-road events that approach, breakover, and departure angles are quantifying. They also stated the static loaded arc radius best reflects the

[1640] NHTSA previously encountered a similar issue when manufacturers reported CAFE footprint information. In the October 2012 final rule, NHTSA clarified manufacturers must submit footprint measurements based upon production values. 77 FR 63138 (October 15, 2012).
[1641] 49 CFR 523.2.

actual condition that exists versus the outside tire diameter.[1642] Finally, the Auto Alliance commented the static loaded arc radius is easy to measure; therefore, the off-road criteria should remain tied to the static loaded arc radius.[1643]

After reviewing the comments, NHTSA agrees that the static loaded arc radius is the most accurate way to account for the condition of the tire and the vehicle-to-ground interaction during off-road events. NHTSA has decided to accept the Auto Alliance's and Fiat Chrysler's views and will retain the existing definitions for off-road angles based upon the static loaded arc radius.

(3) Running Clearance

NHTSA regulations define "running clearance" as "the distance from the surface on which an automobile is standing to the lowest point on the automobile, excluding unsprung weight."[1644] Unsprung weight includes the components (*e.g.*, suspension, wheels, axles, and other components directly connected to the wheels and axles) that are connected and translate with the wheels. Sprung weight, on the other hand, includes all components fixed underneath the vehicle and translate with the vehicle body (*e.g.*, mufflers and subframes). To clarify these requirements, NHTSA previously issued a letter of interpretation stating that certain parts of a vehicle—such as tire aero deflectors that are made of flexible plastic, bend without breaking, and return to their original position—wonld not count against the 20-centimeter running clearance requirement.[1645] The agency explained that this does not mean a vehicle with less than 20-centimeters running clearance could be elevated by an upward force that bends the deflectors and still be considered compliant with the running clearance criterion, as it would be inconsistent with the conditions listed in the introductory paragraph of 49 CFR 523.5(b)(2). Further, NHTSA explained that without a flexible component installed, the vehicle must meet the 20-centimeter running clearance along its entire underside. This 20-centimeter clearance is required for all sprung weight components.

The agency is aware of vehicle designs that incorporate rigid (*i.e.*, inflexible) air dams, valance panels, exhaust pipes, and other components, equipped as manufacturers' standard or optional equipment (*e.g.*, running boards and towing hitches), that likely do not meet the 20-centimeter running clearance requirement. Despite these rigid features, it appears manufacturers are not taking these components into consideration when making measurements. Additionally, NHTSA believes some manufacturers may provide dimensions for their base vehicles without considering optional or various trim level components that may reduce the vehicle's ground clearance. Consistent with our approach to other measurements, NHTSA believes that ground clearance, as well as all the other off-highway criteria for a light truck determination, should use the measurements from vehicles with all standard and optional equipment installed, at the time of

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[1642] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1643] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1644] *Id.*
[1645] *See* letter to Mark D. Edie, Ford Motor Company, July 30, 2012, available at https://isearch.nhtsa.gov/files/11-000612%20M.Edie%20(Part%20523).htm.

the first retail sale.[1646] The agency reiterates that the characteristics listed in 49 CFR 523.5(b)(2) are characteristics indicative of off-highway capability. A fixed feature—such as an air dam that does not flex and return to its original state or an exhaust that could detach—inherently interferes with the off-highway capability of these vehicles. If manufacturers seek to classify these vehicles as light trucks under 49 CFR 523.5(b)(2) and the vehicles do not meet the four remaining characteristics to demonstrate off-highway capability, they must be classified as passenger cars.

In the NPRM, NHTSA sought public comments on how to consider components such as air dams, exhaust pipes, and other hanging component features—especially those that are inflexible—as relates to running clearance and whether the agency should consider amending its definition in Part 523 to account for these components. The Auto Alliance and three automobile manufacturers—Fiat Chrysler, Hyundai, and Kia—commented on the questions. The Auto Alliance and Fiat Chrysler commented that no change is needed for the 20-centimeter running clearance requirement for fixed features of the vehicle; all fixed components must have 20-centimeter of running clearance.[1647] They agreed that flexible components that bend without breaking and return to their original position do not count against the 20-centimeter running clearance requirement.[1648] They disagreed with NHTSA's position that these requirements should apply to all vehicles with standard and optional equipment installed at the time of the first retail sale and proposed instead that the requirement should be "as shipped to the dealer."[1649] Additionally, the Auto Alliance asked NHTSA to make a specific allowance for vehicles that have adjustable ride height, such as air suspension, and permit the running clearance and other off-road clearance measurements to be made in the lifted or off- road mode.[1650] Hyundai and Kia urged NHTSA not to modify the definition of "running clearance," which currently is defined as "the distance from the surface on which an automobile is standing to the lowest point on the automobile, excluding unsprung weight."[1651]

Based upon the comments above, NHTSA has decided to retain its running clearance requirements for qualifying light trucks without change. First, running clearance means the distance from the surface on which an automobile is standing to all fixed components under the vehicle, excluding unsprung components, axle clearance components and flexible components that bend without breaking and returning to their original position as explained in NHTSA's previous interpretation. Second, NHTSA acknowledges that at this time, during validation testing for running clearance, a vehicle with optional equipment installed will only be tested "as

[1646] *See* NHTSA's footprint test procedure for verifying CAFE standards uses vehicles equipped at time of first retail sale. *See* TP-537-01 located at https://www.nhtsa.gov/vehicle-manufacturers/test-procedures.
[1647] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1648] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1649] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1650] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1651] Hyundai, Detailed Comments, EPA-HQ-OAR-2018-0283-4411; Kia, Detailed Comments, EPA-HQ-OAR-2018-0283-4195.

shipped to the dealer." NHTSA has found that optional equipment can impact a vehicle's ability to comply with running clearance requirements, while optional equipment must be considered for other light truck agency validation tests unless the equipment has no impact on the outcome of the test.

(4) Front and Rear Axle Clearance

NHTSA regulations state that front and rear axle clearances of not less than 18 centimeters are another criterion that can be used for designating a vehicle as off-highway capable.[1652] The agency defines "axle clearance" as the vertical distance from the level surface on which an automobile is standing to the lowest point on the axle differential of the automobile.[1653]

The agency believes this definition may be outdated because of vehicle design changes, including axle system components and independent front and rear suspension components. In the past, traditional light trucks with and without 4WD systems had solid rear axles with center-mounted differentials on the axle. For these trucks, the rear axle differential was closer to the ground than any other axle or suspension system component. This traditional axle design still exists today for some trucks with a solid chassis (also known as body-on-frame configuration). Today, however, many SUVs and CUVs that qualify as light trucks are constructed with a unibody frame and have unsprung (*e.g.*, control arms, tie rods, ball joints, struts, shocks, etc.) and sprung components (*e.g.*, the axle subframes) connected together as a part of the axle assembly.[1654] These unsprung and sprung components are located under the axles, making them lower to the ground than the axles and the differential, and were not contemplated when NHTSA established the definition and the allowable clearance for axles. The definition also did not originally account for 2WD vehicles with GVWRs greater than 6,000 pounds that had one axle without a differential, such as the model year 2018 Ford Expedition. Vehicles with axle components that are low enough to interfere with the vehicle's ability to perform off-road would seem inconsistent with the regulation's intent of ensuring off-highway capability, as Congress required.[1655]

In light of these issues, comments were sought in the NPRM on whether (and if so, how) to revise the definition of axle clearance. NHTSA sought comments on what unsprung axle components should be considered when determining a vehicle's axle clearance. The agency questioned whether the definition for axle clearance should be modified to account for axles without differentials. NHTSA also sought comment on whether the axle subframes surrounding the axle components but affixed directly to the vehicle unibody as sprung mass (lower to the ground than the axles) should be considered in the allowable running clearance discussed above. Finally, NHTSA sought comments on whether it should consider replacing both the running and

[1652] 49 CFR 523.5(b)(2)(v).
[1653] 49 CFR 523.2.
[1654] Unibody frames integrate the frame and body components into a combined structure.
[1655] 49 U.S.C. 32901(a)(18)(A).

axle clearance criteria with a single ground clearance criterion that considers all components underneath the vehicle that impact a vehicle's off-road capability.

Comments were received from the Auto Alliance, Fiat Chrysler, Hyundai, and Kia. All the manufacturers that commented claimed no change is needed to the current definition, regardless of whether the axle components are sprung or unsprung masses, as the bottom of the differential is the vulnerable component.[1656] The Auto Alliance also stated there is no need to further modify the definition to account for axles without differentials. Further, the Auto Alliance does not think a single criterion that considers all components under the axle is needed and prefers to keep the existing regulation.[1657] Fiat Chrysler and the Auto Alliance also recommended that 2WD SUVs and CUVs be reclassified back into the truck fleet, where they had been placed prior to the 2011 MY. Their position is that 2WD SUVs are designed to meet the "off-road-capable" definition in NHTSA's rules by having the required running and/or axle clearances as well as meeting other off-road dimensional criteria.[1658] Hyundai stated that changing the point of measurement now would have significant development and economic impacts.[1659] Kia stated that it has designed its vehicles and developed product plans in reliance on the current definitions, and those designs and product plans cannot be modified cheaply or quickly.[1660]

NHTSA already addressed the comments on 2WD SUVs in a previous rulemaking, and NHTSA has no additional response at this time.[1661] Upon review of other comments, manufacturers did not clearly distinguish which parts of the axle sub-frames should be considered as sprung masses in order for NHTSA to understand if modifications are needed to its axle clearance requirements. Therefore, at this time, NHTSA is retaining its axle clearance requirements as currently specified. However, NHTSA still believes it is beneficial to continue efforts at defining those axle components that are sprung or unsprung masses before considering any changes to its regulatory provisions. In addition, NHTSA needs to understand any significant developmental and economic impacts that might be associated with any possible changes to its requirements. Therefore, NHTSA will consider collecting further information on these issues and may take further action related to this issue in the future.

[1656] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Hyundai, Detailed Comments, EPA-HQ-OAR-2018-0283-4411; Kia, Detailed Comments, EPA-HQ-OAR-2018-0283-4195.

[1657] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

[1658] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

[1659] Hyundai, Detailed Comments, EPA-HQ-OAR-2018-0283-4411.

[1660] Kia, Detailed Comments, EPA-HQ-OAR-2018-0283-4195.

[1661] No new arguments have been raised beyond those already considered in the April 6, 2006, final rule (*see* 71 FR 17566).

B. EPA Compliance and Enforcement

1. Overview of the EPA Compliance Process

EPA established comprehensive vehicle certification, compliance, and enforcement provisions for the GHG standards as part of the rulemaking establishing the initial GHG standards for MY 2012-2016 vehicles.[1002] Manufacturers have been following these provisions since MY 2012 and EPA did not propose or seek comments on changing its compliance and enforcement program. ~~This section discusses EPA's processes for its comprehensive light-duty motor vehicle program to ensure compliance with emissions standards for carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4), as described in Section [xxx].[1003] In 2010, EPA and NHTSA finalized a joint rulemaking establishing coordinated CAFE and CO_2 fleet average standards for MYs 2010-2016, which included coordinated compliance requirements and processes.[1004] In its role as part of the joint program, the EPA has designed and implemented an effective compliance program capable of achieving the environmental and public health benefits promised by its mobile source CO_2 standards. EPA's CO_2 compliance program is designed around two overarching priorities: (1) to address the Clean Air Act (CAA) requirements and policy objectives; and (2) to streamline the compliance process for both manufacturers and EPA by building on existing practices wherever possible, and by structuring the program such that manufacturers can use a single data set to satisfy both CO_2 and CAFE testing and reporting requirements. The EPA and NHTSA joint compliance program recognizes, and replicates as closely as possible, the compliance protocols associated with the existing CAA Tier 2 vehicle emission standards, and the existing CAFE standards established pursuant to the Energy Policy and Conservation Act of 1975 (EPCA). In establishing the CAFE program through EPCA in the 1970s, congress gave EPA the statutorily designated responsibility for managing the testing, data collection, and calculation procedures of the CAFE program.[1005] EPA's experience with that program enabled EPA to integrate its CO_2 requirements with the longstanding CAFE requirements such that little to no additional test data is required and data and reporting requirements are largely synchronized. Thus, EPA requires and uses the same test data to determine a manufacturer's compliance with both the CAFE standards and the fleet average CO_2 emissions standards.~~

~~Compliance with the fleet average CO_2 standards in a given model year is determined based on testing, performed prior to production, and on actual vehicle production in that model year, as with the current CAFE standards. Manufacturers start compliance with the EPA program in advance of each model year by certifying how their products will comply with CO_2~~

Commented [A421]: DELETE: EPA sees no reason to include this text in the Final SAFE rule, which did not appear in the NPRM.

EPA did not propose or ask for comment in the SAFE NPRM any changes to the basic aspects of the now long-standing GHG compliance program, and are not finalizing any changes. In addition, this text describes some program elements that were transitional and thus are no longer part of the program.

Please note that EPA did not review the deleted text for accuracy.

[1002] See 75 FR 25468-25488 and 77 FR 62884-62887 for a description of these provisions. See also "The 2018 EPA Automotive Trends Report, Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975," EPA-420-R-19-002 March 2019 for additional information regarding EPA compliance determinations.

~~[1003] The EPA program applies to passenger automobiles and light trucks and includes (1) fleet average CO_2 emissions standards; and (2) fixed nitrous oxide (N_2O) and methane (CH_4) exhaust emissions standards or the option to combine N_2O and CH_4 emissions into a fleet average carbon-related exhaust emissions (CRE) value as specified in 40 CFR part 600, subpart I.~~

~~[1004] See 88 FR 25326.~~

~~[1005] See 49 U.S.C. 32904(c).~~

~~standards and requirements as mandated by 40 CFR 86.1843-01. A representative vehicle within each test case is used to certify the model types within each manufacturer's fleet of passenger cars or light trucks.[***] The EPA program does not distinguish between import and domestic passenger car fleets, unlike the CAFE program. Upon successful certification of each model type, manufacturers may introduce vehicles into commerce. Next, throughout the model year, manufacturers establish test results for all the vehicles within each model type and EPA oversees the manufacturers' testing. Manufacturers conduct their CO_2 and CAFE testing over an entire model year to maximize efficient use of testing and engineering resources. Manufacturers then submit their final CO_2 and CAFE test results to EPA and EPA subsequently conducts confirmatory testing at its laboratory on a subset of the manufacturer's vehicles to determine compliance with the CO_2 standards. Emission levels can only be determined when a complete fleet profile becomes available at the close of the model year. Under this coordinated approach, the compliance mechanisms for both the CO_2 and CAFE programs are consistent and non-duplicative.~~

~~The EPA compliance program not only assesses compliance with the CO_2 standards but also assesses compliance with in-use standards. Vehicle emission standards established under the CAA apply throughout a vehicle's full useful life. EPA determines in-use standards by adding an adjustment factor to the emission results used to calculate the fleet averages.[****] The EPA program also includes requirements for manufacturers to provide warranty, defect reporting, and other emission-related component provisions promulgated in the MY's 2012–2016 rulemaking. EPA uses a variety of compliance mechanisms to validate fleet average and in-use standards, including pre-production certification and postproduction, in-use monitoring after vehicles enter customer service.~~

~~Under the EPA compliance program, manufacturers have a number of flexibilities and incentives to help achieve compliance. Examples include credit banking, transfers and trading, incentives for certain technologies such as battery electric vehicles and fuel cell vehicles, exemptions for certain vehicles, and alternate small manufacturer-specific CO_2 fleet average standards. In this rulemaking, EPA and NHTSA are finalizing new CO_2 and CAFE standards under which manufacturers will continue to perform the same model level compliance processes currently required for the CO_2 and CAFE programs. These compliance processes remain in place without significant modifications. In the NPRM, EPA sought comments on possible changes to a number of its flexibilities and incentives. The following sections summarize the comments received and provide EPA's responses. For context, the EPA process for determining compliance and how manufacturers use the EPA flexibilities and incentives are explained in the following sections as well.~~

~~EPA's CO_2 Program Compliance~~

~~Manufacturers plan their compliance strategies far in advance of each model year. Manufacturers also contact EPA to discuss their strategies and plans for certifying each model~~

~~[***] A model type is "a unique combination of car line, basic engine, and transmission class." 40 CFR 600.002.~~

~~[****] The values are adjusted to be 10% higher to account for test-to-test and production variability that might affect in-use test results.~~

~~type to comply with the CO_2 standards separately for their passenger car fleet and for their light truck fleet. CAA Section 203(a)(1) prohibits manufacturers from introducing a new motor vehicle into commerce unless the vehicle is covered by an EPA-issued certificate of conformity. Section 206(a)(1) of the CAA describes the requirements for EPA issuance of a certificate of conformity, based on a demonstration of compliance with the emission standards established by EPA under Section 202 of the Act. EPA issues certificates of conformity pursuant to Section 206 of the Act, based on (necessarily) pre-sale testing conducted either by EPA or by the manufacturer. The Federal Test Procedure (FTP or "city" test) and the Highway Fuel Economy Test (HFET or "highway" test) are used for this purpose. The certification demonstration requires emission testing that must be done for each model year.[***] EPA's certification program for vehicles also allows manufacturers to carry certification test data over and across certification testing from one model year to the next, when no significant changes to models are made. EPA applies this policy to CO_2, N_2O, and CH_4 certification test data and allows manufacturers to use carryover and "carry across" data to demonstrate CO_2 fleet average compliance if they have done so for CAFE purposes. For test groups that are using carryover data for certification, EPA allows those test groups to carryover the N_2O compliance statement (now allowed through MY 2016) into MYs 2017 and 2018.~~

~~Because compliance with a fleet average standard depends on actual production volumes, it is not possible to determine compliance with the fleet average at the time the manufacturer applies for and receives a certificate of conformity for a test group. Instead, EPA continues to issue and compile the results of each certificate of conformity for the CO_2 program through December 31st of each given model year. After the model year ends, EPA calculates the fleet average emission compliance level using actual production volumes and the CO_2 emission test values for each model type. EPA also calculates the fleet average standard based on the CO_2 emission target values from the footprint-based target curve and the production volume of each model type. EPA then compares the actual fleet average to the manufacturer's footprint-based standard to determine compliance, taking into consideration any flexibility credits and incentives like off-cycle and air conditioning credits, banked and transferred credits, and LV vehicle incentive multipliers. Final determination of compliance with fleet average CO_2 standards may not occur until one or two years after the close of the model year due to the time required for manufacturers to submit information and for EPA compliance review to be completed. A failure to meet the fleet average standard after compliance flexibilities have been exhausted could ultimately result in penalties and injunctive orders under the CAA.~~

~~*a. How Does EPA Determine Compliance?*~~

~~Compliance with EPA CO_2 standards is determined after the end of the model year when final compliance information on the vehicles manufactured for sale is available. As noted above, under the footprint-based standards, a manufacturer's ultimate compliance obligations are determined after the end of each model year when the production of vehicles for that model year is complete. Since the fleet average standards that apply to a manufacturer's car and truck fleets are based on the applicable footprint-based curves, a production volume-weighted fleet average requirement will be calculated for cars and trucks based on the mix and volumes of the models~~

~~[***] CAA Section 206(a)(1)~~

~~manufactured for sale by the manufacturer. If a manufacturer's car and or truck fleet achieves a fleet average CO_2 level better than its car and or truck standards, then the manufacturer generates compliance credits. Conversely, if the fleet average CO_2 level does not meet the standard, the fleet incurs compliance debits (also referred to as a shortfall). For each model year, a manufacturer also gains credits for model types equipped with certain technologies qualifying for additional flexibilities and incentives, including for A/C systems with improved efficiency or resistance to leakage, off-cycle technologies, and hybrid-electric full-size pickup trucks.~~

~~Under the EPA compliance program, a manufacturer whose fleet generates a shortfall in a given model year may have several options for using compliance credit flexibilities, including credit carry-back, credit carry-forward, credit transfer, and credit trade or comply using additional credits generated by installing A/C systems with improved efficiency or resistance to leakage, off-cycle technologies, or hybrid-electric full-size pickup trucks or comply using any combination of these flexibilities and incentives. These compliance credit provisions are consistent with similar CAFE program provisions that have existed since the inception of the CAFE program or as added under EPCA and EISA through rulemaking and available starting with the 2011 or 2017 model years.[xxxv] EPA's Tier 2 program for light-duty vehicle criteria pollutant emissions uses similar credit provisions, as do many other mobile source standards issued by EPA under the CAA. Under the CO_2 program, if credits are unavailable in the current model year, manufacturers may carry credit deficits forward for a period of up to three model years after the deficit occurs. After that time, if credits are still not available, EPA determines that the manufacturer is not in compliance. EPA does not permit manufacturers to pay fines in lieu of compliance with applicable standards; EPA's authority under the CAA requires EPA to revoke a noncompliant manufacturer's certificate of conformity, which permits the manufacturer to sell vehicles.[xxxvi] Under Section 203 of the CAA, sales of vehicles are prohibited unless the vehicle is covered by a certificate of conformity.~~

~~Compliance with the governing standards is required not only at certification, but throughout a vehicle's useful life, and compliance testing may continue after certification. Useful life standards apply an adjustment factor to account for vehicle emission control deterioration or variability in use (Section 206(a)). The useful life CO_2 standard for each model type would be the model-specific CO_2 level used in calculating the fleet average, adjusted to be 10% higher to account for test-to-test and production variability that might affect in-use test results. Section 207 of the CAA also grants EPA broad authority to require manufacturers to remedy vehicles if EPA determines there are a substantial number of non-complying vehicles. In addition, Section 205 of the CAA authorizes EPA to assess penalties of up to $37,500 per vehicle for commission of various prohibited acts specified in the CAA. In determining the appropriate~~

~~[xxxv] The benefit for A/C systems, off-cycle, and advanced full-size pickup trucks are calculated as additional credits under the EPA compliance program although are not credits under the CAFE program, rather A/C, off-cycle, and pickup-truck benefits are realized as fuel consumption improvement values to increase a manufacturer's fuel economy value.~~

~~[xxxvi] Section 205 of the Clean Air Act authorizes EPA to assess penalties of up to $37,500 per vehicle for violations of various prohibited acts specified in the Clean Air Act. In determining the appropriate penalty, EPA must consider a variety of factors such as the gravity of the violation, the economic impact of the violation, the violator's history of compliance, and "such other matters as justice may require." Unlike EPCA, the CAA does not authorize vehicle manufacturers to pay fines in lieu of meeting emission standards.~~

~~penalty, EPA must consider a variety of factors such as the gravity of the violation, the economic impact of the violation, the violator's history of compliance, and "such other matters as justice may require."~~

~~Section 203 of the CAA also describes acts that are prohibited by law. This section and the corresponding regulations apply equally to the CO_2 standards as to any other regulated emissions. Acts that are prohibited by Section 203 of the CAA include the introduction into commerce or the sale of a vehicle without a certificate of conformity, removing or otherwise defeating emission control equipment, the sale or installation of devices designed to defeat emission controls, and other related actions. EPA finalized language in the 2012 CO_2 regulations that details the specific prohibited acts under the Clean Air Act.~~

~~To aide manufacturers in the compliance process, EPA provides a number of flexibilities and incentives for manufacturers to meet compliance with fleet average CO_2 standards. These flexibilities and incentives are expected to incentivize the production of certain vehicles and provide sufficient lead time for manufacturers to make necessary technological improvements and reduce the overall cost of the program without compromising overall environmental and fuel economy objectives. The broad goal of harmonizing the two agencies' standards and compliance processes includes preserving manufacturers' flexibilities in meeting the standards, to the extent appropriate and required by law.~~

~~b. What Exemptions and Exclusions does EPA allow?~~

~~(1) Emergency and Law Enforcement Vehicles~~

~~For EPA, police and other emergency vehicles are exempt from the CO_2 standards, as adopted for MY 2012 and later model years. Under EPCA, manufacturers are also allowed to exclude police and other emergency vehicles from their CAFE fleet and all manufacturers that produce emergency vehicles have historically done so. EPA adopted an exemption equivalent to the EPCA exemption, which allows manufacturers to exempt police and emergency vehicles upon sending notification to EPA (the same notification that is sent to NHTSA is shared). EPA continues to believe it is appropriate to provide an exemption for these vehicles because the unique features of vehicles designed specifically for law enforcement and emergency response purposes have the effect of raising their CO_2 emissions, as well as for purposes of harmonization with the CAFE program. Therefore, no comments were sought in the NPRM or received, and EPA will retain the exemption as currently existing.~~

~~(2) Small Business and Small Volume Manufacturers~~

~~Small business manufacturers meeting the Small Business Administration (SBA) size criteria set forth in 13 CFR 121.201 are exempt from EPA's CO_2 standards given that these businesses face unique challenges in satisfying the standards. For vehicle manufacturers, SBA's definition of a small business is any firm with less than 1,500 employees. This includes both U.S. based and foreign small businesses in three distinct categories for light-duty vehicles: small volume manufacturers, independent commercial importers (ICIs), and alternative fuel vehicle converters. These businesses account for less than 0.1 percent of the total car and light truck~~

~~sales in the U.S., thus the exemption has a negligible impact on overall CO_2 reductions. To ensure that EPA knows which businesses are exempt, EPA requires each such entity to submit a written declaration detailing how it qualifies as a small business under 13 CFR 121.201. The program also allows small businesses to waive their exemption and voluntarily comply with the CO_2 standards. For example, a small manufacturer of electric vehicles could choose to comply if it is interested in generating CO_2 credits and potentially participating in the credit market.~~

~~Similar to small businesses, in the MYs 2012-2016 EPA program, the agency recognized that some very small volume manufacturers (i.e., manufacturers with limited product lines and production volumes that do not meet the SBA definition of a small business) would likely find the CO_2 standards to be extremely challenging and potentially infeasible to satisfy, at least absent purchase of credits from other manufacturers. Starting with the 2017 compliance model year, eligible small volume manufacturers (SVMs) have the option to petition EPA to develop an alternative CO_2 standard for their company, determined on a case-by-case basis in a public process. For MYs 2012-2016, these same manufacturers were excluded from complying with CO_2 standards by following the same petitioning process. This flexibility mirrors the CAFE alternative standards for small business set forth in 49 CFR part 525. SVMs are exempt from meeting CO_2 standards if they have annual U.S. sales less than 5,000 vehicles. An eligible manufacturer must first make a good faith effort to secure credits from other manufacturers, if they are reasonably available, to cover the emissions reductions they would have otherwise had to achieve under applicable standards. An SVM utilizing this option would then submit data and information that EPA would use in addition to other available information to establish CO_2 standards for that specific manufacturer. EPA also extended eligibility for the SVM CO_2 provisions to very small manufacturers that are owned by large manufacturers, but which are able to establish that they are operationally independent.~~

~~EPA believes its exemptions are fair and equitable for these specific types of manufacturers and, therefore, did not request comments in the NPRM to consider changes to its provisions. Consequently, EPA is retaining the existing exemptions without any further modifications.~~

~~*(3) Temporary Lead-Time Allowance Alternative Standards (TLAAS)*~~

~~By way of background, the TLAAS provisions provide additional lead time for limited volume manufacturers, whereby a specified number of vehicles are subject to a less stringent standard in either MYs 2012-2015, or (for smaller volume manufacturers) MY 2016. Manufacturers with limited product lines were noted by EPA to be especially challenged in the early years of the joint program, and needing additional lead time. Manufacturers with narrow product offerings were not able to take full advantage of averaging or other program flexibilities due to the limited scope of the types of vehicles they sell. For example, some smaller volume manufacturer fleets consist entirely of vehicles with very high baseline CO_2 emissions. Their vehicles are above the CO_2 emissions target for that vehicle footprint, but do not have other types of vehicles in their production mix with which to average. These manufacturers frequently pay fines under the CAFE program rather than meet the applicable CAFE standard.~~

~~EPA determined that these technological circumstances warranted more lead time in the form of a more gradual phase-in of standards. A manufacturer may qualify for the temporary lead time allowance if it sold vehicles in the U.S. in MY 2009 and its U.S. vehicle sales in that model year were below 400,000 vehicles. Upon satisfying the threshold criteria, a manufacturer is permitted to treat a limited number of vehicles as a separate averaging fleet for MYs 2012-2015, which are subject to a less stringent CO_2 standard. Specifically, a standard of 25 percent above the vehicle's otherwise applicable foot-print target level will apply to up to 100,000 vehicles total, spread over the four year period of MY 2012 through 2015. Thus, the number of vehicles to which the flexibility could apply is limited. EPA is also setting appropriate restrictions on credit use for these vehicles, as discussed further in Section III. By MY 2016, these allowance vehicles must be averaged into the manufacturer's full fleet (i.e., they will no longer be eligible for a different standard). EPA discusses this in more detail in Section III B of the preamble.~~

~~c.~~a. *What Compliance Flexibilities and Incentives Are Currently Available Under the CO_2 Program and How Do Manufacturers Use Them?*

Under EPA's regulations~~Section 202 (a) of the CAA~~, manufacturers can use credit flexibilities to comply with CO_2 standards for passenger car or light truck compliance fleets. Similar to the CAFE program, manufacturers gain credits when the performance of a fleet exceeds its required CO_2 fleet average standard which can be carried forward for five years. EPA also allows a one-time credit carry-forward exceeding 5 years, allowing MY 2010-2015 to be carried forward through MY2021. A manufacturer's fleet performance ~~that falls below the level of a~~that does not meet the fleet average standard ~~earns~~ generates a credit deficit. Manufacturers can carry credit deficits forward up to three model years before having to resolve the shortfall.

~~However, to facilitate the transition to the increasingly more stringent standards, EPA proposed, and is finalizing under its CAA authority, a one-time CO_2 carry-forward beyond 5 years such that any credits generated from MYs 2010 through 2016 may be used to comply with light duty vehicle CO_2 standards at any time through MY 2021. This provision does not apply to early credits generated in MY 2009.~~

NHTSA's program will continue the 5-year carry-forward and 3-year carryback, as required by statute. Credit "transfer" means the ability of manufacturers to move credits from their passenger car fleet to their light truck fleet, or vice versa. As part of the EISA amendments to EPCA, NHTSA was required to establish by regulation a CAFE credit transferring program, now codified at 49 CFR part 536, to allow a manufacturer to transfer credits between its car and truck fleets to achieve compliance with the standards. For example, credits earned by over-compliance with a manufacturer's car fleet average standard could be used to offset debits incurred because the manufacturer did not meet the truck fleet average standard in a given year.

Under Section 202(a) of the CAA, there is no statutory limitation on car/truck credit transfers, and EPA's CO_2 program allows unlimited credit transfers across a manufacturer's car and light truck fleets to meet CO_2 standards.

EPA requested comment on a variety of "enhanced flexibilities" whereby EPA could make adjustments to current incentives and credit provisions and potentially add new flexibility opportunities to expand the means by which manufacturers may satisfy standards. Some of these additional flexibilities would not result in a reduction in program stringency, while others would incentivize technologies that could realize greater CO_2 emissions reductions over a longer term, but would result in a loss of emission benefits in the short-term, as discussed below. EPA requested comments on these topics to support the increased application of technologies that the automotive industry is developing and deploying that could potentially lead to further long-term emissions reductions and allow manufacturers to comply with standards while reducing costs.

EPA explained that one category of flexibilities, such as off-cycle credits and credit banking, involve credits that are based on real world emissions reductions and do not represent a loss of overall emissions benefits or a reduction in program stringency, yet offer manufacturers potentially lower-cost or more efficient path to compliance. Another category of flexibilities, such as incentives for battery electric vehicles, hybrid technologies, and alternative fuels, do result in a loss of emissions benefit and represent a reduction in the effective stringency of the standards to the extent the incentives are used by manufacturers. These incentives would help manufacturers meet a numerically more stringent standard, but would not reduce real-world CO_2 emissions in the short term compared to a lower stringency option with fewer such incentives. EPA's policy rationale for providing such incentives, as articulated in the 2012 rulemaking, was that such programs could incentivize the development and deployment of advanced technologies with the potential to lead to greater CO_2 emissions reductions in the longer-term, where such technologies today are limited by higher costs, market barriers, infrastructure, and consumer awareness.[1671] Such incentive approaches would also result in rewarding automakers who invest in certain technological pathways, rather than being technology neutral.

Prior to the proposal, automakers and other stakeholders expressed support for this type of approach compliance flexibility. For example, in March 2018, Ford stated, "We support increasing clean car standards through 2025 and are not asking for a rollback. We want one set of standards nationally, along with additional flexibility to help us provide more affordable options for our customers."[1672] Honda, in April 2018, also expressed its support for an approach that retained the existing standards while extending the advanced technology multipliers for electrified vehicles, eliminated automakers' responsibility for the impact of upstream emissions from the electric grid, and accommodated more off-cycle technologies.[1673]

EPA's request for comments was largely based on its consideration of input from automakers and other stakeholders, including suppliers and alternative fuels industries, supporting a variety of program flexibilities.[1674] The following provides an overview of EPA's

[1671] *See* 77 FR 62810-62826 (Oct. 15, 2012).
[1672] "A Measure of Progress" Bill Ford, Executive Chairman, Ford Motor Company, and Jim Hackett, President and CEO, Ford Motor Company, March 27, 2018, https://medium.com/cityoftomorrow/a-measure-of-progress-bc34ad2b0cd.
[1673] Honda Release "Our Perspective – Vehicle Greenhouse Gas and Fuel Economy Standards," April 20, 2018, http://news.honda.com/newsandviews/pov.aspx?id=10275-en.
[1674] Memorandum to docket EPA-HQ-OAR-2018-0283 regarding meetings with the Alliance of Automobile Manufacturers on April 16, 2018 and Global Automakers on April 17, 2018. EPA-HQ-OAR-2018-0283-0022.

request for comments on several flexibility concepts, the comments EPA received, and the agency's response to those comments. After considering comments and the level of stringency of the final revised standards, EPA is not adopting new incentives in the areas of credit multipliers (with the exception of multipliers for natural gas vehicles), new incentives for hybrid vehicles, incentives for autonomous or connected vehicles, or alternative fueled vehicles other than natural gas, as part of this final rule. EPA is finalizing program changes for the treatment of upstream emissions for electric vehicles, the treatment of natural gas vehicles, and off-cycle credits, as discussed below.

(1) *Credit Flexibilities*

Commented [A422]: REVISE: Note that the following section contains multiple comments and revisions both improve clarity and correct factual errors

Under the EPA program, CO_2 credits may be carried forward, or banked, for a period of five years, with the exception that MY 2010-2015 credits may be carried forward and used through MY 2021. CO_2 credits may also be traded between manufacturers and transferred between passenger car and light truck fleets similar to the CAFE program, but without any adjustment for fuel savings. Under Section 202(a) of the CAA, there is no statutory limitation on credit transfers between a manufacturer's passenger car and light truck fleets, and EPA's CO_2 program allows unlimited credit transfers across a manufacturer's passenger car and light truck fleets to comply with CO_2 standards. This flexibility is based on the expectation that it will help facilitate manufacturer compliance with CO_2 standards in the lead time provided, and allow CO_2 emissions reductions to be achieved in the most cost effective way. ~~EPA provided another credit flexibility as a one-time provision allowing manufacturers to generate credits for the 2009-2011 model years. This allowed manufacturers to take advantage of credit opportunities prior to the start of the federal tailpipe CO_2 emissions program in MY 2012.~~

Automakers suggested, prior to the NPRM proposal, a variety of ways in which CO_2 credit life could be extended under the CAA, like allowing automakers to carry-forward MY 2010 and later banked credits to MY 2025, extending the life of credits beyond five years, or even unlimited credit life where credits would not expire. EPA requested comments in the NPRM on extending credit carry-forward under the CO_2 program beyond the current five years, including unlimited credit life.

~~In the NPRM, EPA stated it believes longer credit life could provide manufacturers with additional flexibility to integrate banked credits further into their product plans and potentially reduce costs. As a result, EPA requested comments on extending credit carry-forward beyond the current five years, including unlimited credit life.~~ General comments were received in response to the NPRM from the National Automobile Dealers Association and Volkswagen. They commented that credit carry-forward and carryback options help with annual compliance with the CO_2 program.[1675] They stated that these mechanisms allow manufacturers to become compliant over the course of the time a credit is usable in the market.[1676] Toyota, General Motors, Fiat Chrysler, the Auto Alliance, and the Global Automakers each commented that CO_2

[1675] National Automobile Dealers Association, Detailed Comments, NHTSA-2018-0067-12064; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1676] *See, e.g.*, National Automobile Dealers Association, NHTSA-2018-0067-12064.

credits earned by manufacturers need a longer life so they may be carried forward further than the current five-year limitation.[1677] They asked for an unlimited period for using CO_2 credits without restrictions, since they argues that automakers have earned those credits and should be allowed to use them however they see fit.[1678] They also stated that this would incentivize manufacturers to make early reductions in CO_2 emissions.[1679] Furthermore, it was noted that credits are earned when manufacturers achieve lower CO_2 fleet average emissions than otherwise required by regulation in any given model year. They stated that this typically results from actions taken by a manufacturer to deploy specific models or more efficient technology than required, often at a higher cost. Such technologies reduce the amount of CO_2 emissions released into the atmosphere over the life of the vehicle, which could be over several decades. Therefore, the resulting credit earned by a manufacturer for having made the product or technology investment that resulted in the reduced emissions should not be limited to five years.

Global Automakers, the Auto Alliance, Fiat Chrysler, and Toyota requested a one-time expiration date extension through 2026 for CO_2 credits earned in MYs 2010-2015.[1680] They asserted that earned credits represent actual CO_2 reductions and increasing their lifespan will allow for better compliance. Conversely, Honda disagreed with the extension of MY 2010-2015 credits through 2026 because they have been selling their credits under the assumption that they would expire.[1681] Honda stated that shorter life (soon to expire) credits are worth less than longer life credits, leading to a disadvantage for manufacturers who have already sold these credits at a lower price. Honda asserted that the one-time extension would benefit only a few automakers.[1682] However, Honda did agree that a one-time extension through 2026 for MYs 2016-2020 CO_2 credits would assist with compliance because these credits have yet to be involved in trades.[1683]

In sum, commenters requested either unlimited allowances to carry-forward surplus credits without any expiration date, a one-time expiration date extension through 2026 for CO_2 credits earned from MY 2010 and later, or consideration for extending credit life longer than the current five-year provision. After considering the comments received, EPA has decided not to change its credit carry-forward provisions at this time, and will retain the credit carry-forward period under the CO_2 program at five years for credits generated in MYs 2016 and later. EPA requested comments on extended carry-forward, along with the other flexibilities discussed in this section, as potential ways of helping manufacturers to transition to more stringent standards than proposed. However, given the level of the standards finalized today, EPA does~~stated that it did~~ not believe any changes to its credit carry-forward provisions ~~we~~were warranted. EPA

[1677] Toyota, Detailed Comments, NHTSA-2018-0067-12150; General Motors, Detailed Comments, NHTSA-2018-0067-11858; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.
[1678] *See, e.g.*, Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.
[1679] *See, e.g.*, General Motors, Detailed Comments, NHTSA-2018-0067-11858.
[1680] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Toyota Detailed Comments, NHTSA-2018-0067-12150.
[1681] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1682] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1683] Honda, Detailed Comments, NHTSA-2018-0067-11818.

notesalso acknowledges that NHTSA's CAFE program is constrained by statute to a five-year carry-forward so if EPA adopted a longer carry-forward period, it might be of limited use since the level of stringency of the CO_2 and CAFE standards is similar across the programs. Also, the analysis on which the tailpipe CO_2 emissions standards finalized today are based, assumed a five-year carry-forward period for credits.

~~Another reason for denying manufacturers' requests is the inequitable advantage a longer credit life will have for manufacturers with surplus credits especially those with significant amounts of credits currently banked for multiple model years. These manufacturers will have even larger volumes of credits available to them after adjustments for fuel savings are applied to future model years with higher CO_2 standards. Manufacturers without credits, or manufacturers who have already sold their credits at current market values based on the present five-year carry-forward credit lifespan, as Honda discussed, will be significantly disadvantaged.[1683] These manufacturers are unlikely to be able to renegotiate the price of credit trades already made. Manufacturers with large amounts of credits would clearly be advantaged and able to distort the market in ways unfavorable to the goal of reducing emissions. EPA is concerned that these manufacturers will be able to create uncertainties in the market by being able to infuse large volumes of credits into future model years where it may even be possible to delay some cost-effective technologies from entering production because manufacturers are relying upon these credits as an alternative pathway to compliance.~~

Commented [A423]: DELETE: EPA does not agree with the characterization or the credit market portrayed in this response, and does not believe it is necessary to support EPA's decision to retain the current credit carryforward period. Therefore EPA suggests deleting entirely.

(2) *Advanced Technology Incentives*

The existing EPA GHG~~CO~~$_2$ program provides incentives for electric vehicles, fuel-cell vehicles, plug-in hybrid vehicles, and natural gas vehicles. The 2012 rulemaking allowed manufacturers to use a 0 grams/mile emissions factor for all electric powered vehicles rather than having to account for the CO_2 emissions associated with upstream electricity generation, up to a per-manufacturer cumulative production cap for MYs 2022-2025. The program also includes multiplier incentives that allow manufacturers to count advanced technology vehicles as more than one vehicle in the compliance calculations. The multipliers began with MY 2017 and end after MY 2021.[1685] Prior to the proposal, stakeholders suggested that these incentives should be expanded to support further the production of advanced technologies by allowing manufacturers to continue to use the 0 grams/mile emissions factor for electric powered vehicles rather than having to account for upstream electricity generation emissions and by extending and potentially increasing the multiplier incentives.

First, EPA requested comments on extending the use of 0 grams/mile emissions factor for electric powered vehicles.

The Auto Alliance, Global Automakers, and several manufacturers commented that upstream utility emissions come from power plants, not vehicle tailpipes, and manufacturers

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~~[1683] Honda, Detailed Comments, NHTSA-2018-0067-11618.~~

[1685] The multipliers are for EV/FCVs: 2017–2019—2.0, 2020—1.75, 2021—1.5; for PHEVs and dedicated and dual-fuel CNG vehicles: 2017–2019—1.6, 2020—1.45, 2021—1.3.

have no control over the feedstock used by those power plants and should not be held responsible for their upstream electricity emissions.[1686] The Auto Alliance further commented that removing upstream accounting is not an incentive for advanced technology vehicles; rather, it should be seen as a correction to remove responsibility for emissions over which the automakers have no control.[1687] Fiat Chrysler commented that "requiring upstream accounting could impede development of BEVs or PHEVs, as accounting of upstream emissions degrades the CO_2 performance of BEVs to the level of PHEVs, and PHEVs to the level of a conventional hybrid electric vehicle. This, in effect, disincentivizes the technology."[1688]

Several other commenters also supported not counting upstream emissions and instead only counting electric powered vehicle tailpipe emissions of 0 grams/mile.[1689] These commenters included NCAT, SAFE, BorgWarner, CALSTART, Eaton, and Edison Electric Institute.

API did not support continuing the 0 grams/mile emission factor for electricity use, commenting that by failing to factor the real contribution of upstream CO_2 emissions from electric generation, the regulatory agencies would distort the market for developing transportation fuel alternatives.[1690] API commented that EPA should not ignore the environmental burden of upstream emissions in granting production incentives to automakers.

Manufacturers of Emission Controls Association (MECA) commented that "with the growing emphasis on real-world emission reductions, it becomes increasingly important to consider all emissions to the environment, including upstream emissions. Numerous studies have shown that in many parts of the country, the temporary 0 grams/mile upstream emissions factor is not delivered in the real-world … MECA believes that EPA should continue to set performance-based standards that assess technology pathways based on delivering the intended emission reductions over the full well-to-wheels vehicle life cycle in the real-world."[1691] Motor & Equipment Manufacturers Association (MEMA) also supported a well-to-wheel fuel lifecycle approach, commenting that without this type of comprehensive assessment on the fuel impacts and comprehensive CO_2 costs, policies improperly "slant toward preferred technologies."[1692] Nonetheless, MEMA commented that it is not opposed to continuing to allow 0 grams/mile emissions factor for electric powered vehicles through 2026.

The Union of Concerned Scientists (UCS) commented that not accounting for upstream emissions combined with the multipliers has a significant impact on the efficacy of the standard, and extending these regulatory incentives is more likely to result in a credit giveaway than to drive additional deployment of electric vehicles.[1693] UCS further commented that, to date, more

[1686] *See, e.g.*, Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1687] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1688] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1689] *See, e.g.*, NCAT, NHTSA-2018-0067-11969.
[1690] API, Detailed Comments, EPA-HQ-OAR-2018-0283-5458.
[1691] MECA, Detailed Comments, NHTSA-2018-0067-11994.
[1692] MEMA, EPA-HQ-OAR-2018-0283-5692. *See* https://www.mema.org/sites/default/files/resource/MEMA%20CAFE%20and%20GHG%20Vehicle%20Comments%20FINAL%20with%20Appendices%20Oct%2026%202018.pdf.
[1693] UCS, Detailed Comments, NHTSA-2018-0067-12039.

than half of the electric vehicles sold have been in California and the states that have adopted California's ZEV standards; however, UCS asserted, federal standards ignore the upstream emissions for all vehicles sold.

After carefully considering the wide range of comments on whether to include upstream emissions associated with electricity use in the compliance calculations for electrified vehicles, EPA has decided to allow the continued use of the 0 grams/mile emissions factor with no per-manufacturer production caps or other limitations. EPA is revising its regulations to remove the production caps and related provisions. When EPA initially adopted a production cap for manufacturers that use the 0 grams/mile emissions factor, in the rulemaking to establish CO_2 standards for MY 2012-2016 vehicles, there were no controls in place for CO_2 emissions from electricity production.[1694] This was also the case when EPA extended the 0 grams/mile upstream provision and revised the production caps in the rule establishing MY 2017-2025 standards.[1695] However, since then, EPA has adopted a program to control CO_2 emissions from power plants.[1696] Emissions from the power sector have been declining and that trend is projected to continue.[1697] For these reasons, EPA no longer views the upstream emissions factor as an incentive in the same way it views a multiplier incentive which provides bonus credits. EPA agrees that, at this time, manufacturers should not account for upstream utility emissions. Therefore, EPA is adopting regulatory changes consistent with its historical practice of basing compliance with vehicle emissions standards on tailpipe emissions through model year 2026. EPA may choose to reconsider this decision in a future CO_2 rulemaking, and will reexamine the issue when establishing standards commencing with the 2027 model year.

Second, EPA requested comments on extending or increasing advanced technology incentives, including multiplier incentives, with multipliers in the range of 2.0-4.5. EPA received a wide range of comments both for and against increasing the multiplier incentives. The MY 2017-2025 GHG44 program finalized in 2012 included incentive multipliers for certain advanced technologies for MY 2017-2021 vehicles.

The Auto Alliance, Global Automakers, and several individual manufacturers commented in support of continued and increased multipliers. The Auto Alliance commented that EPA should extend and significantly expanding multipliers "to encourage a transition to these technologies while cost, range, and infrastructure challenges are addressed to encourage ongoing investments in advanced technologies."[1698] Global Automakers commented that multipliers should be included through MY 2026, set at values that encourage ongoing investment in advanced technologies, without diluting overall efficiency improvements in the program.[1699] NCAT, Eaton, Plug-in America, Alliance to Save Energy, SAFE, and MEMA also

[1694] 75 FR 25341, May 7, 2010.
[1695] 77 FR 62816, October 15, 2012.
[1696] 84 FR 32520, July 8, 2019.
[1697] 84 FR 32561.
[1698] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1699] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.

supported additional multiplier incentives to encourage further the production and sale of advanced technology vehicles.[1700]

EPA also received comments against extending the multiplier credits. UCS commented that reducing the stringency of the standards lessens the need for the adoption of these vehicles and undermines the initial rationale for these credits, resulting in a significant bank of credits which would further erode the benefits of these standards.[1701] American Council for an Energy-Efficient Economy (ACEEE) commented that providing multiplier incentives for any longer period, or at a greater rate than those currently in place, would create windfall credits for manufacturers given the industry's current product plans.[1702] Fiat Chrysler commented generally in support of a multiplier incentive, but noted that since multipliers are a GHG~~CO~~-only flexibility not present in the CAFE program, greater use of multipliers would result in further disharmonizing the programs.[1703] API commented against multipliers, stating that the program should be technology neutral and that regulatory agencies should not incentivize either producer or consumer investments in government-selected technologies applied to government-selected vehicle categories.[1704]

In this final rule, EPA is neither adopting any additional multipliers nor extending the existing multipliers scheduled to phase out after MY 2021 for EVs, PHEVs, and FCVs. Compliance with the final revised standards is projected to be achievable without a substantial increase in these advanced technology vehicles and therefore additional incentives to encourage their production are unnecessary. EPA is also concerned that additional multiplier incentives beyond those already in place for these vehicles which are currently available to consumers would reduce the emissions benefits associated with the program. As discussed below in section IX.B.1.a.(3)(b), EPA is providing an additional multiplier for dedicated and dual-fuel NGVs, which are not currently produced by auto manufacturers, for MYs 2022-2026. ~~EPA notes the CO_2 program already provides a significant incentive for PHEVs, EVs, and FCVs by only counting tailpipe emissions (not accounting for upstream emissions).~~

Commented [A424]: REVISE: Edits to reflect EPA's NGV multiplier.

(3) Special Considerations

(a) Incentives for Connected or Automated Vehicles

Connected and automated (including autonomous) vehicles have the potential to impact significantly vehicle emissions in the future, with their aggregate impact being either positive or negative, depending on a large number of vehicle-specific and system-wide factors. EPA noted in the proposal that connected or automated vehicles would be eligible for credits under the off-cycle program if a manufacturer provides data sufficient to demonstrate the real-world emissions

[1700] NCAT, Detailed Comments, NHTSA-2018-0067-11969; Eaton, Detailed Comments, EPA-HQ-OAR-2018-0283-5068; Plug-In America, Detailed Comments, NHTSA-2018-0067-12028; Alliance to Save Energy, Detailed Comments, NHTSA-2018-0067-11837; SAFE, Detailed Comments, NHTSA-2018-0067-11981; *see* https://www.mema.org/sites/default/files/resource/MEMA%20CAFE%20and%20GHG%20Vehicle%20Comments%20FINAL%20with%20Appendices%20Oct%2026%202018.pdf.
[1701] UCS, Detailed Comments, NHTSA-2018-0067-12039.
[1702] ACEEE, Detailed Comments, NHTSA-2018-0067-12122.
[1703] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1704] API, Detailed Comments, EPA-HQ-OAR-2018-0283-5458.

benefits of such technology applied to its vehicles. However, demonstrating the incremental real-world benefits of these emerging technologies will be challenging. Prior to the proposal, stakeholders suggested that EPA should consider an incentive for these technologies without requiring individual manufacturers to demonstrate real-world emissions benefits of the technologies. A number of stakeholders also requested that EPA consider credits for automated and connected vehicles that are placed in ridesharing or other high mileage applications, where any potential environmental benefits could be multiplied due to the high utilization of these vehicles. EPA requested comment on such incentives as a way to facilitate increased use of these technologies, including some level of assurance that they will lead to future additional emissions reductions. For example, EPA stated in the proposal that any near-term incentive program should include some demonstration that the technologies will be both truly new and have some connection to overall environmental benefits. EPA further outlined and sought comment on several approaches to incentivize automated and connected vehicle technologies.

EPA received comments supporting and opposing incentives for automated and connected vehicles. The Auto Alliance commented that the agencies should incentivize the adoption of these technologies and provide for possibly additional credit once the benefits beyond the credit values have been confirmed.[1705] It further commented that a growing body of modeling results, as well as real-world driving statistics, show that current automated driving technologies improve real-world fuel efficiency and reduce CO_2 emissions. SAFE commented that connected automated vehicles have tremendous potential to save lives, and when combined with ride-sharing and electric powertrains, they can also increase efficiencies and save fuel.[1706] SAFE argued that an initial review of the literature shows the potential for these technologies to improve fuel economy by up to 25 percent when they are optimized and aggregated alongside other traditional efficiency technologies. Toyota commented that automated vehicles, and possibly new mobility models such as ridesharing, can help attain societal goals concerning climate change, energy security, traffic congestion, and safety.[1707] Ford commented that it is supportive of credits for future connected and automated vehicles and that autonomous vehicles are considered the future of personal mobility, with many manufacturers announcing plans to release autonomous-capable vehicles in the near term.[1708] Ford added that these vehicles have the potential to not only provide meaningful real-world CO_2 and fuel economy benefits, but also add true societal benefit for the public good by providing transportation to those who would otherwise not have access. General Motors and Jaguar Land Rover commented in favor of additional credits for vehicles placed in ride-sharing or high mileage applications.[1709]

~~CARB asserted new compliance flexibilities for autonomous vehicles are not appropriate.[1710] It stated that manufacturers are already anticipating bringing autonomous~~

Commented [A425]: DELETE: This comment is covered below.

[1705] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1706] SAFE, Detailed Comments, NHTSA-2018-0067-11981.
[1707] Toyota, Detailed Comments, NHTSA-2018-0067-12150.
[1708] Ford, Detailed Comments, NHTSA-2018-0067-11928.
[1709] General Motors, Detailed Comments, NHTSA-2018-0067-11858; Jaguar Land Rover, Detailed Comments, NHTSA-2018-0067-11916.
~~[1710] CARB, Detailed Comments, NHTSA-2018-0067-11873.~~

technologies to their fleets, making these flexibilities unnecessary.[1711] Conversely, SAFE commented that autonomous vehicles will lead to new jobs and better worker productivity. It stated that these vehicles will also reduce congestion and lead to safer travel.[1712]

Other commenters opposed incentives for automated and connected vehicles, generally commenting that while the technologies are promising, the impacts of the technologies remain highly uncertain and therefore incentives are not appropriate. ACEEE commented that EPA should not incentivize technologies such as automated vehicle technology or ridesharing services, unless and until it can be demonstrated that such an incentive will result in emissions reduction benefits and will not undermine the existing standards.[1713] ACEEE believes that there currently exists no real-world data to justify granting of off-cycle credits for automated vehicle technologies, and that providing automakers credits for deploying technologies which are driven by demands other than fuel savings and emissions reduction only allows them to make fewer real-world emissions reductions elsewhere. ACEEE further stated that while automated vehicles promise all-new possibilities and efficiencies in transportation and the use of infrastructure, the net impact on transportation sector energy use and emissions is unknown.

UCS commented that the "evidence to-date does not warrant incentivizing such technologies—there is no provable environmental benefit of such technologies, and the agencies have previously correctly acknowledged that any such potential impacts would be related to indirect benefits, which raise serious concerns about compliance and enforcement to ensure the integrity of the program."[1714] Honda commented that there remains considerable uncertainty in the literature regarding the energy and environmental benefits (or negative benefits) of connected/automated vehicle technology.[1715] Honda commented that if technology benefits can be verified under robust, repeatable conditions, they should warrant off-cycle credits under the existing off-cycle program. Honda does not believe credits should be granted for application of technology alone.

CARB commented that new compliance flexibilities (or off-cycle credit categories) for automated vehicles are not appropriate at this time.[1716] CARB believes that, although the technology is widely expected to provide safety and mobility benefits, automakers are expected to bring the technology to market regardless, so incentives are unnecessary, and it is not established that these technologies will reduce emissions given their potential for high annual mileage. Resources for the Future commented they do not see a rationale for providing special credits to automated vehicles since such vehicles could increase or decrease emissions.[1717] Competitive Enterprise Institute (CEI) commented that some connected and/or automated vehicle technology applications—namely platooning—may improve fuel efficiency through improved aerodynamics and thus reduce CO_2 emissions; however, such applications to date are

[1711] CARB, Detailed Comments, NHTSA-2018-0067-11873.
[1712] SAFE, Detailed Comments, NHTSA-2018-0067-11981.
[1713] ACEEE, Detailed Comments, NHTSA-2018-0067-12122.
[1714] USC, Detailed Comments, NHTSA-2018-0067-12039.
[1715] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1716] CARB, Detailed Comments, NHTSA-2018-0067-11873.
[1717] Resources for the Future, Detailed Comments, NHTSA-2018-0067-11789.

limited to heavy-vehicle prototypes beyond the scope of this rulemaking and in any event should be subject to verification prior to any award of off-cycle credits.[1718] CEI commented further: "We urge EPA to preserve the existing off-cycle program requirement that manufacturers demonstrate CO_2 emissions reductions prior to the award of credits, rather than picking technology winners and losers that have nothing to do with fuel economy or emissions." National Association of Truck Stop Operators (NATSO) commented against incentives, stating that although automated vehicles have the potential positively to transform transportation (and indeed day-to-day life) in the U.S., there are also a number of complexities and potential costs associated with them.[1719]

EPA is not adopting new incentives for automated and connected vehicles. While EPA agrees there may be potential for such technologies to reduce emissions long-term, depending on how the technologies are developed, implemented, and used, EPA remains concerned about the high degree of uncertainty regarding the impacts of the technologies and potential loss of emissions reductions associated with such incentives. EPA agrees with the comments that, at this time, it is more appropriate for manufacturers to seek credits through the existing off-cycle credits program where manufacturers would be required to provide data demonstrating direct emissions improvements for the technologies.

(b) Natural Gas Vehicle (NGV) Credits

Vehicles that are able to run on compressed natural gas (CNG) are eligible for an advanced technology multiplier credit for MYs 2017-2021, as discussed in the Advanced Technology Incentives section above. Dual-fueled natural gas vehicles, which can run either on natural gas or on gasoline, also may use utility factors higher than 0.5 when weighting tailpipe emissions measured over the test procedures while operating on natural gas and gasoline test fuels if the vehicles meet minimum design criteria, including minimum CNG range requirements. Prior to the proposal, EPA received input from several industry stakeholders that supported expanding these incentives to stimulate production of vehicles capable of operating on natural gas, including treating incentives for natural gas vehicles on par with those for electric vehicles and other advanced technologies, and adjusting or removing the minimum range requirements for dual-fueled CNG vehicles. EPA requested comments on these potential additional incentives for natural gas fueled vehicles.

Among comments received regarding incentives for NGVs, Ariel Corporation and VNG together commented that NGVs can be effectively promoted by providing a level playing field and regulatory parity with EVs.[1720] They stated, "an effective alternative compliance pathway for NGVs can be established with a few simple changes to the regulations including applying the '0.15 divisor' to emissions calculations, which would harmonize EPA's regulations with the statutory CAFE program, and recognize the real-world emissions benefits of RNG [renewable natural gas], and provide NGVs with reasonable parity with EVs." Ariel and VNG commented also that EPA should offer advanced technology production multipliers for NGVs on par with

[1718] CEI, Detailed Comments, EPA-HQ-OAR-2018-0283-4166.
[1719] NATSO, Detailed Comments, EPA-HQ-OAR-2018-0283-5484.
[1720] Joint Submission from Ariel Corp. and VNG.co, Detailed Comments, NHTSA-2018-0067-7573.

EVs and FCVs, with NGVs receiving these incentives at the same level and for the same duration as electric and fuel-cell vehicles. The commenters believe~~It believes~~ that while NGVs have lower technology hurdles than these vehicles, they face similar infrastructure challenges and offer similar or superior emissions benefits through the use of RNG.

Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association~~'s joint submission,~~ commented in a joint submission that NHTSA and EPA should use this rulemaking opportunity to expand incentives for NGVs and thereby increase the availability of NGVs in the light-duty sector, particularly for pickup trucks, work vans, and sport utility vehicles.[1721] These commenters also submitted comments supporting additional incentives for full-size pickup NGVs and incentives for vehicles equipped to be converted to operate on natural gas. Coalition for Renewable Natural Gas, et al., commented that allowing 0 grams/mile accounting for electricity use is favorable to electric vehicles because it allows electric vehicle manufacturers to take credit for anticipated improvements in emissions associated with the electric grid resulting from increased use of natural gas and renewable energy.[1722] It further commented that given the significant amount of renewable natural gas currently being used and projected to be used in future years, using a factor of 0.15 or even greater to offset NGV emissions is warranted because RNG use reduces carbon dioxide emissions by 85 percent or more in most cases. Ingevity similarly commented in support of EPA including a 0.15 multiplier incentive for purposes of CO_2 compliance parity between natural gas and electric dual-fuel vehicles as necessary and critical to promote the commercialization of light-duty natural gas vehicles and stimulate the increased utilization of RNG. Ingevity added that growth in the natural gas vehicle market is necessary to meet future RFS obligations.[1723]

United States Senator James M. Inhofe commented that "even if all current incentives for EVs are eliminated, EVs still have a compliance advantage going forward. This is because the policy and technical approaches underlying the [CO_2] regulations embedded preferential treatment for the previous administration's favored technology. I respectfully ask you not to give NGVs preferential treatment, but to level the playing field to allow the marketplace to determine the future of NGV adoption and not the federal bureaucracy. To achieve this parity, reinstating the 0.15 [CO_2] multiplier is essential."[1724]

In addition to supporting the application of a 0.15 factor, the natual gas industry also commented in support of production multipliers for NGVs. Ariel and VNG commented that EPA should offer advanced technology production multipliers for NGVs on par with EVs and FCVs, with NGVs receiving these incentives at the same level and for the same duration as electric and fuel cell vehicles. Ingevity commented that dual-fuel and dedicated NGV multipliers should be extended through 2025 as an effective way to promote the commercialization of these kinds of vehicles by the automakers. NGVAmerica et al. commented that "NGVs, both dedicated and

Commented [A426]: CHANGE AS SHOWN: This is the placeholder for the NGV Multiplier.

[1721] Joint Submission from the Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association, Detailed Comments, NHTSA-2018-0067-11967.
[1722] Joint Submission from the Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association, Detailed Comments, NHTSA-2018-0067-11967.
[1723] Ingevity, Detailed Comments, NHTSA-2018-0067-8666.
[1724] James M. Inhofe, Detailed Comments, EPA-HQ-OAR-2018-0283-7456.

dual-fuel, should be provided with the same vehicle production multiplier credits as have previously been, and continue to be, provided to EVs and FCVs. Given that the expected and likely range capabilities of NGVs will generally exceed EV ranges (including natural gas dual-fuel vehicles that significantly outperform the range capabilities of PHEVs which justifiably enjoy a lower multiplier as compared to EVs), the vehicle production multipliers that are used for EVs should be applied to NGVs, including dual fuel NGVs. Specifically, dedicated and dual-fuel NGVs (or all covered advanced technology vehicles) should receive a base multiplier of 2.0 (or any such higher multiplier afforded to EVs FCVs) for at least model years 2019 through 2021 and the same multipliers afforded to EVs FCVs thereafter through 2025."

National Association of Convenience Stores (NACS) and the Society of Independent Gasoline Marketers of America (SIGMA) commented, "the Associations urge you to treat all fuels and technologies equally, including NGVs, EVs, and petroleum-based motor fuels. It is the role of the Agencies to set performance specifications via notice-and-comment rulemaking to ensure that they are appropriate. Once the specifications are set, however, it should be up to the market to determine how best to meet them."[1725]

UCS commented that natural gas is a potent greenhouse gas, and any direct emissions of methane pose a significant threat to any effort to limit climate change.[1726] UCS stated, "these direct emissions upstream significantly undermine any potential benefit that could come from the pump-to-wheel benefits of displacing gasoline or diesel with natural gas." UCS also commented, "furthermore, the technology underpinning any natural gas-powered vehicle is exceptionally mundane—natural gas has been deployed previously in vehicles like the Honda Civic, and aftermarket CNG conversions have long been available on the market. Again, there is no critical hurdle to overcome with CNG powered vehicles, and there is little if any benefit to any such incentives. We strongly recommend that EPA eliminate all incentives for natural gas vehicles and instead ensure such vehicles are credited commensurate with their impact on the environment." CARB also commented that new compliance flexibilities for NGVs are not appropriate at this time.[1727]

~~EPA requested comments on several incentives discussed in this section. EPA is not adopting new vehicle multiplier incentives for any advanced technology vehicles, including electric vehicles, plug-in hybrids, fuel-cell vehicles, and NGVs, as discussed above.~~

~~[Text Forthcoming]~~

Regarding comments that EPA should provide additional credits to auto manufacturers for the potential use of RNG due to upstream benefits associated with the production of RNG by applying a 0.15 factor, EPA does not agree with these comments since auto manufacturers would not be required to ensure such fuels are used in the vehicles they produce over the life of those vehicles. Commenters provided a rationale for why they believe all NGVs produced in the future will be fueled with RNG, but EPA believes there is no assurance that this would be the

Commented [A427]: CHANGE AS SHOWN: This paragraph is from EPA's draft flexibilities preamble section. It was omitted from this draft, but should be reinstated.

[1725] Joint submission on behalf of NACS and SIGMA, Detailed Comments, EPA-HQ-OAR-2018-0283-5824.
[1726] UCS, Detailed Comments, NHTSA-2018-0067-12039.
[1727] CARB, Detailed Comments, NHTSA-2018-0067-11873.

case. If fossil fuel-based natural gas is used in the vehicles, the environmental benefits asserted by the commenters would not exist and the substantial vehicle incentives recommended by the commenters would result in a loss of environmental benefits. EPA does not believe it is appropriate to attribute most or all of the potential benefit of the production and use of RNG to the vehicle manufacturer. EPA's Renewable Fuel Standards (RFS) already appropriately credits RNG use as compared to fossil fuel-based natural gas. The RFS program provides a substantial incentive for RNG production and those incentives may lead to even lower fuel pricing and greater demand for RNG as vehicle fuel, and for NGVs in the future. The RFS program also can provide incentives for liquid cellulosic fuels, advanced bio-diesel, and other types of renewable transportation fuels. Consistent with EPA's decision not to include upstream emissions associated with electricity use for EVs and PHEVs discussed above, EPA believes it is appropriate at this time to maintain the focus of the light-duty vehicle GHG standards on the capabilities of the vehicle to control emissions, and not rely on lifecycle fuel characteristics as a basis for developing specific vehicle incentives, particularly where those fuels are already incentivized by the RFS program.

After considering comments regarding incentive multipliers for NGVs and the current lack of light-duty NGV offerings by OEMs in the market, EPA has decided to include a multiplier incentive of 2.0 for MY 2022-2026 dedicated and dual-fuel NGVs. This multiplier will begin when the previously established multipliers expire, thus extending the mulipler for NGVs for 5 years beyond those previously established for NGVs. While other alternative fuel vehicles that were provided multiplier incentives are increasingly available in the light-duty marketplace, no OEM is currently offering light-duty NGVs. Since Honda ended production of the CNG version of the Honda Civic at the end of MY 2015, there have been no OEM NGV offerings available to consumers. EPA continues to believe that NGVs could be an important part of the overall light-duty vehicle fleet mix and such offerings would enhance the diversity of potentially cleaner alternative fueled vehicles available to consumers.[728] EPA believes it is appropriate to extend the availability of a production multiplier through MY 2026 for both dual-fuel and dedicated NGVs to potentially help spur their re-introduction by OEMs in the light-duty vehicle market.

EPA also received comments on the application of the regulatory utility factor. For dual-fuel vehicles, emissions are measured on both fuels (e.g., gasoline and natural gas) and weighted using a factor referred to in the regulations as a utility factor. To use a utility factor for natural gas greater than 0.5, a dual-fuel NGV must meet design criteria requiring the vehicle to have a natural gas to gasoline driving range of 2:1. The vehicle must also preferentially operate on natural gas until the natural gas tank is empty. EPA adopted these design criteria as part of the 2012 final rule to help ensure vehicles using a utility factor of higher than 0.5 would likely be fueled with and use natural gas most of the time on the road. At that time, EPA was concerned that natural gas refueling may be much more inconvenient for drivers relative to electric charging for PHEVs due to a lack of CNG refueling stations (or home refueling, compared to the availability of home chargers for many PHEVs) and, therefore, dual-fuel vehicles with limited driving range on natural gas would likely frequently operate on gasoline.

[728] The CNG Honda Civic had approximately 20 percent lower CO_2 than the gasoline Civic in MY 2015.

EPA received comments regarding the design criteria. Ingevity commented that it has developed a low-pressure (900 psi) adsorbed natural gas (ANG) fuel storage technology that allows vehicles to be refueled using an affordable and reliable low-pressure natural gas fueling appliance.[1729] Ingevity commented that ANG will allow for a distributed refueling network at users' homes and businesses, just like electrical recharging equipment has been installed for PHEVs over the last several years. Ingevity commented that the design criteria for dual-fuel NGVs that were established in the MYs 2017-2025 final rule "make it impossible to reasonably and affordably manufacture a dual-fuel NGV that can fully utilize the utility factor (UF) approach for determining fuel economy and [CO_2] emissions." Ingevity recommended that the design criteria for dual-fuel NGVs be removed and that the utility factor be based only on the range of the NGV on natural gas, equivalent to the treatment of PHEVs. MECA submitted similar comments regarding ANG technology.[1730]

Ariel and VNG also commented that design criteria imposed on dual-fuel NGVs add unnecessary costs and complexity, and currently are arbitrarily applied only to dual-fuel NGVs, and not to their dual-fuel hybrid counterparts.[1731] NACS, SIGMA, and NATSO also recommended that EPA remove eligibility requirements associated with the utility factor.[1732]

After considering the comments, EPA is removing the design criteria from the regulations and thereby allowing higher utility factors to be used for dual-fuel natural gas vehicles based solely on driving range on natural gas, as is the case for PHEVs. The utility factor represents a reasonable way of weighting the emissions of a dual-fuel vehicle on each fuel to derive a single emissions value when including the dual-fuel vehicles in a manufacturer's fleet average compliance determination. Ideally, the utility factor would match the use of each fuel in real-world vehicle operation. The utility factor is not meant to incentivize the adoption of a particnlar technology, so it differs fundamentally from incentives such as multipliers. With the development of low-pressure natural gas vehicle fueling system technology since the 2012 final rule, EPA's concerns regarding limited fueling infrastructure that led the agency to adopt the design criteria in the 2012 rule are significantly diminished. EPA believes that low-pressure fueling is a new advancement that offers the potential for more convenient refueling for individuals or businesses similar to that for PHEVs. EPA expects owners of dual-fuel CNG vehicles preferentially to seek to refuel and operate on CNG fuel as much as possible, both because the owner would have to pay a higher vehicle price for the dual-fuel capability, and because CNG fuel is considerably cheaper than gasoline. With the opportunity for relatively low-cost on-site refueling at homes or businesses, EPA expects such vehicles to be refueled with natural gas similar to how people refuel PHEVs. Vehicle purchasers that choose high pressure vehicle systems over low pressure systems would likely do so only if they have ready access to a high pressure refueling system, for example, at a fleet's central fueling location. Removing the design criteria for dual-fuel natural gas vehicles also addresses the concerns of some commenters regarding the differing treatment of PHEVs and dual-fuel NGVs.

[1729] Ingevity, Detailed Comments, NHTSA-2018-0067-8666.
[1730] *See* MECA, Detailed Comments, NHTSA-2018-0067-11999.
[1731] Joint Submission from Ariel Corp. and VNG, Detailed Comments, NHTSA-2018-0067-7573.
[1732] Joint submission on behalf of NACS and SIGMA, Detailed Comments, EPA-HQ-OAR-2018-0283-5824; NATSO, Detailed Comment, EPA-HQ-OAR-2018-0283-5484.

EPA believes that with the advancement of technology offering the potential for more flexible refueling of NGVs, removing the design criteria is a reasonable change to the regulations. This regulatory change will apply starting with MY 2021. MY 2021 will provide sufficient time for orderly implementation and EPA is not aware of any dual-fuel NGVs emissions certified for MYs 2019-2020 that would otherwise be affected if this change were to be implemented sooner.

C. NHTSA Compliance and Enforcement

1. Overview of the NHTSA Compliance Process

Consumer choice drives the mixture of automobiles on the road. Manufacturers largely produce a mixture of vehicles to meet consumer demand and address compliance with CAFE standards though the application of fuel economy improving technologies to those vehicles, and by using compliance flexibilities and incentives that are available in the CAFE program. As discussed earlier in this notice, each vehicle manufacturer is subject to separate CAFE standards for passenger cars and light trucks, and for the passenger car standards, a manufacturer's domestically-manufactured and imported passenger car fleets are required to comply separately.[1733] Additionally, domestically-manufactured passenger cars are subject to a statutory minimum standard.[1734] CAFE program flexibilities are largely provided for in statute.

Commented [A428]: REVISE: May want to clarify that credits for air conditioning efficiency, off-cycle, and pickup truck advanced technologies are not expressly specified by CAFE statute, but are "implemented consistent with EPCA's provisions regarding calculation of fuel economy" as discussed in section C.2 below.

Compliance with the CAFE program begins with manufacturers submitting required reports to NHTSA in advance and during the model year that contain information, specifications, data, and projections about their fleets.[1735] Manufacturers report early product projections to NHTSA describing their efforts to comply with CAFE standards per EPCA's reporting requirements.[1736] Manufacturers' early projections are required to identify any of the flexibilities and incentives manufacturers plan to use for air-conditioning (A/C) efficiency, off-cycle and full-size pickup truck advanced technologies. EPA consults with NHTSA when reviewing and considering manufacturers' requests for fuel consumption improvement values for A/C and off-cycle technologies that improve fuel economy. NHTSA evaluates and monitors the performance of the industry using the information provided. NHTSA also audits manufacturers' projected data for conformance and verifies vehicle design data through testing to ensure manufacturers are complying as projected. After the model year ends, manufacturers submit final reports to EPA, including final information on all the flexibilities and incentives allowed or approved for

[1733] 49 U.S.C. 32904(b).
[1734] 49 U.S.C. 32902(b)(4).
[1735] 49 U.S.C. 32907(a); 49 CFR 537.7.
[1736] 49 U.S.C. 32907(a).

the given model year.[1737] EPA then calculates the fuel economy level of each fleet produced by each manufacturer, and transmits that information to NHTSA.[1738]

NHTSA notes that some manufacturers have submitted and/or resubmitted requests for A/C and off-cycle benefits after EPA final reports are completed or nearly completed and, in those cases, such submissions are causing considerable delays in EPA's ability to finalize CAFE reports. Late and revised submissions can place significant burdens on the government in order to reassess a manufacturer's CAFE performances and standards and can also cause significant impacts on previous compliance model years. In the following sections, EPA and NHTSA are incorporating regulatory modifications or providing guidance to help manufacturers expedite approvals and to facilitate the governments processing of the ~~new~~ flexibilities and incentives.

NHTSA determines each manufacturer's obligation to comply with applicable model year's CAFE standards and notifies the manufacturer if any of its fleet performances fall below standards. Manufacturers must submit plans detailing the compliance flexibilities to be used to resolve any possible noncompliances or may pay civil penalties to address any deficits for falling below standards. NHTSA periodically releases data and reports to the public through its CAFE Public Information Center (PIC) based on information in the EPA final reports for the given compliance model year, and based on the projections manufacturers provide to NHTSA for the next two model years.[1739]

2. NHTSA's CAFE Program Compliance

EPCA and EISA specify several flexibilities and incentives that are available to help manufacturers comply with CAFE standards. Some flexibilities are defined, and sometimes limited, by statute – for example, while Congress allowed manufacturers to transfer credits earned for over-compliance from their car fleet to their truck fleet and vice versa, Congress also limited the amount by which manufacturers could increase their CAFE levels using those transfers.[1740] Consistent with the limits Congress placed on certain statutory flexibilities and incentives, NHTSA crafted and implements the credit transfer and trading regulations authorized by EISA to help ensure that total fuel savings are preserved when manufacturers exercise statutory compliance flexibilities.

NHTSA and EPA have previously developed other compliance flexibilities and incentives for the CAFE program consistent with the statutory provisions regarding EPA's calculation of manufacturers' fuel economy levels. As discussed previously, NHTSA finalized in the 2012 final rule, for MYs 2017 and later, an approach for manufacturers' "credits" under

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[1737] For example, alternative fueled vehicles get special calculations under EPCA (49 U.S.C. 32905-06), and fuel economy levels can also be adjusted to reflect air conditioning efficiency and "off-cycle" improvements, as discussed below.

[1738] 49 U.S.C. 32904(c)-(e). EPCA granted EPA authority to establish fuel economy testing and calculation procedures; EPA uses a two-year early certification process to qualify manufacturers to start selling vehicles, coordinates manufacturer testing throughout the model year, and validates manufacturer-submitted final test results after the close of the model year.

[1739] NHTSA CAFE Public Information Center, https://one.nhtsa.gov/cafe_pic/CAFE_PIC_Home.htm.

[1740] *See* 49 U.S.C. 32903(g).

EPA's program to be applied as fuel economy "adjustments" or "improvement values" under NHTSA's program for: (1) technologies that cannot be measured or cannot be fully measured on the 2-cycle test procedure, i.e., "off-cycle" technologies; and (2) A/C efficiency improvements that also improve fuel economy but cannot be measured on the 2-cycle test procedure. Additionally, both agencies' programs give manufacturers compliance incentives for utilizing specified technologies on pickup trucks, such as pickup truck hybridization.

The following sections outline how NHTSA determines whether manufacturers are in compliance with the CAFE standards for each model year, and how manufacturers may use compliance flexibilities, or address noncompliance by paying civil penalties. As addressed above, some compliance flexibilities are expressly prescribed in statute and some are implemented consistent with EPCA's provisions regarding calculation of fuel economy. NHTSA proposed new language updating and clarifying existing regulatory text in this area as part of the NPRM. NHTSA also sought comments in the NPRM on these changes, as well as on the general efficacy of these flexibilities in the fuel economy and CO_2 programs.

Moreover, the following sections explain how manufacturers submit data and information to the agency. As part of the NPRM, NHTSA proposed to implement a new standardized template for manufacturers to use to submit CAFE data to the agency, as well as a standardized template for reporting credit transactions. Additionally, NHTSA proposed adding requirements that specify the precision of the fuel savings adjustment factor in 49 CFR 536.4. These new requirements are intended to streamline reporting and data collection from manufacturers, in addition to helping the agency use the best available data to inform CAFE program decision makers. The comments received to these proposals are included in Section VIII.C.2.a)(2)(d) along with NHTSA's responses to the comments and final resolutions ~~to be~~ established in the final rule.

NHTSA also sought comments on removing or modifying certain CAFE program flexibilities. The comments received and NHTSA's responses to those comments are discussed below.

a) How does NHTSA Determine Compliance?

(1) Manufacturers Submit Data to NHTSA and EPA and the Agencies Validate Results

EPCA, as amended by EISA, requires a manufacturer to submit reports to the Secretary of Transportation explaining whether the manufacturer will comply with an applicable CAFE standard for the model year for which the report is made; the actions a manufacturer has taken or intends to take to comply with the standard; and other information the Secretary requires by regulation.[1741] A manufacturer must submit a report containing the above information during the 30-day period before the beginning of each model year, and during the 30-day period beginning

[1741] 49 U.S.C. 32907(a).

the 180th day of the model year.[1742] When a manufacturer determines it is unlikely to comply with a CAFE standard, the manufacturer must report additional actions it intends to take to comply and include a statement about whether those actions are sufficient to ensure compliance.[1743]

To implement these reporting requirements, NHTSA issued 49 CFR Part 537, "Automotive Fuel Economy Reports," which specifies three types of CAFE reports that manufacturers must submit. A manufacturer must first submit a pre-model year (PMY) report containing the manufacturer's projected compliance information for that upcoming model year. By regulation, the PMY report must be submitted in December of the calendar year prior to the corresponding model year.[1744] Manufacturers must then submit a mid-model year (MMY) report containing updated information from manufacturers based upon actual and projected information known midway through the model year. By regulation, the MMY report must be submitted by the end of July for the applicable model year.[1745] Finally, manufacturers must submit a supplementary report to supplement or correct previously submitted information, as specified in NHTSA's regulation.[1746]

If a manufacturer wishes to request confidential treatment for a CAFE report, it must submit both a confidential and redacted version of the report to NHTSA. CAFE reports submitted to NHTSA contain estimated sales production information, which may be protected as confidential until the termination of the production period for that model year.[1747] NHTSA temporarily protects each manufacturer's competitive sales production strategies, but does not permanently exclude sales production information from public disclosure. Sales production volumes are part of the information NHTSA routinely makes publicly available through the CAFE PIC.

The manufacturer reports provide information on light-duty automobiles such as projected and actual fuel economy standards, fuel economy performance values, and production volumes, as well as information on vehicle design features (e.g., engine displacement and transmission class) and other vehicle attribute characteristics (e.g., track width, wheelbase, and other off-road features for light trucks). Beginning with MY 2017, to obtain credit for fuel economy improvement values attributable to additional technologies, manufacturers must also provide information regarding A/C systems with improved efficiency, off-cycle technologies (e.g., stop-start systems, high-efficiency lighting, active engine warm-up), and full-size pickup trucks with hybrid technologies or with emissions/fuel economy performance that is better than footprint-based targets by specified amounts. This includes identifying the makes and model types equipped with each technology, the compliance category those vehicles belong to, and the associated fuel economy improvement value for each technology.[1748] In some cases, NHTSA may require manufacturers to provide supplementary information to justify or explain the

[1742] *Id.*
[1743] *Id.*
[1744] 49 CFR 537.5(b).
[1745] *Id.*
[1746] 49 CFR 537.8.
[1747] 49 CFR part 512, appx. B(2).
[1748] NHTSA collects model type information based upon the EPA definition for "model type" in 40 CFR 600.002.

benefits of these technologies and their impact on fuel consumption or to evaluate the safety implication of the technologies. These details are necessary to facilitate NHTSA's technical analyses and to ensure the agency can perform enforcement audits as appropriate.

NHTSA uses manufacturer-submitted PMY, MMY, and supplementary reports to assist in auditing manufacturer compliance data and identifying potential compliance issues as early as possible. Additionally, as part of its footprint validation program, NHTSA conducts vehicle testing throughout the model year to confirm the accuracy of the track width and wheelbase measurements submitted in the reports.[1749] These tests help the agency better understand how manufacturers may adjust vehicle characteristics to change a vehicle's footprint measurement, and ultimately its fuel economy target. NHTSA also includes a summary of manufacturers' PMY and MMY data in an annual fuel economy performance report made publicly available on its PIC.

NHTSA uses EPA-verified final-model year (FMY) data to evaluate manufacturers' compliance with CAFE program requirements, and draws conclusions about the performance of the industry. After manufacturers submit their FMY data, EPA verifies the information, accounting for NHTSA and EPA testing, and subsequently forwards the final verified data to NHTSA.

(2) Changes to CAFE Reporting Requirements Made by This Final Rule

NHTSA proposed changes to its CAFE reporting requirements with the intent of streamlining data collection and reporting for manufacturers while helping the agency obtain the best available data to inform CAFE program decision-makers. The agency developed two new standardized reporting templates for manufacturers and proposed to start using the templates beginning in the 2019 compliance model year. In the NPRM, NHTSA sought comments on the templates. NHTSA's responses to the comments received and the changes to the templates for the final rule are presented below.

(a) Standardized CAFE Reporting Template

When NHTSA received and reviewed manufacturers' projection reports for MYs 2013 – 2015, the agency observed that most did not conform to the requirements specified in 49 CFR Part 537. For example, NHTSA identified several instances where manufacturers' CAFE reports included a "yes" or "no" response to a request for a vehicle's *numerical* ground clearance values. In a 2015 notice of proposed rulemaking, NHTSA proposed to amend 49 CFR Part 537 to require a new data format for manufacturers' light-duty vehicle CAFE projection reports.[1750] In response to the proposal, some manufacturers commented that the previous changes in reporting requirements generated confusion and led to reporting errors. NHTSA recognized that the

[1749] U.S. Department of Transportation, NHTSA, Laboratory Test Procedure for 49 CFR Part 537, Automobile Fuel Economy Attribute Measurements (Mar. 30, 2009), *available at* http://www.nhtsa.gov/DOT/NHTSA/Vehicle%20Safety/Test%20Procedures/Associated%20Files/TP-537-01.pdf.
[1750] 80 FR 40540 (Jul. 13, 2015).

modification to the base tire definition in the 2012 final rule for MYs 2017 and later seemed to make some manufacturers uncertain about what footprint data was required in the reports.[1751] Specifically, certain manufacturers did not understand that the modified base tire definition required them to provide estimated attribute-based target standards for each unique model type/footprint combination beginning with MY 2013. NHTSA discovered cases where manufacturers only provided target or vehicle data for certified vehicle configurations, and did not report information for each of the unique model type/footprint combinations for their available production vehicles in the market. However, NHTSA did not adopt the proposed data format from the 2015 proposed rule after receiving adverse comments from manufacturers.[1752]

Since the issuance of the final rule in 2016, NHTSA has continued to receive projection reports that contain inaccurate and/or missing data. These noncompliant reports impede NHTSA's ability to audit manufacturer compliance data, identify potential compliance issues, and analyze industry trends. Problems with inaccurate or missing data has become an even greater issue for manufacturers reporting on the new MY 2017 incentives for efficient A/C systems, off-cycle technologies, and full-size pickup trucks with hybrid technologies/improved exhaust emission performance.[1753] These incentives are explained in Section VIII.C.2.c). Manufacturers seeking to take advantage of these new benefits must provide information at the model-type level; however, many manufacturers did not submit the required information in their PMY reports for MYs 2017, 2018, and 2019. This caused NHTSA's Office of Enforcement to send letters reminding manufacturers of their obligation to submit accurate and complete CAFE reports. NHTSA will continue to monitor the accuracy, completeness, and timeliness of manufacturers' CAFE reports and may take additional action as appropriate.

In the NPRM, NHTSA proposed a new standardized template for reporting PMY and MMY information, as specified in 49 CFR 537.7(b) and (c), as well as supplementary information required by 49 CFR 537.8. The template allows manufacturers to build out the required confidential versions of CAFE reports specified in 49 CFR Part 537 and to produce automatically the required non-confidential versions by clicking a button within the template. While NHTSA recognizes that modifications to the reporting requirements may initially be a slight inconvenience to manufacturers, the number of noncompliant reports the agency continues to receive justifies development of a uniform reporting method to help ensure compliance with CAFE regulations. Adopting a standardized template will assist manufacturers in providing the agency with all necessary data, thereby helping manufacturers to ensure they are complying with CAFE regulations. The template organizes the required data in a manner consistent with NHTSA and EPA regulations and simplifies the reporting process by incorporating standardized responses consistent with those provided to EPA. The template collects the relevant data, calculates intermediate and final values in accordance with EPA and NHTSA methodologies, and aggregates all the final values required by NHTSA regulations in a single summary worksheet. Thus, NHTSA believes that the standardized templates will benefit both the agency

[1751] 49 CFR 523.2.
[1752] 81 FR 73958 (Oct. 25, 2016).
[1753] NHTSA allows manufacturers to use these flexibilities and incentives for complying with standards starting in MY 2017.

and manufacturers by helping to avoid reporting errors, such as data omissions and miscalculations, and will ultimately simplify and streamline reporting.

NHTSA proposed to require that manufacturers use the standardized template for all PMY, MMY, and supplementary CAFE reports. NHTSA observed that a significant number of manufacturers submit their MMY reports as updated PMY reports–using the same amount of information, despite fewer data requirements. To conform with this method, NHTSA designed the template based on one standardized format that uses the same data requirements for all CAFE reports. This approach will further simplify CAFE projection reporting for manufacturers. The template contains a few additional data fields for certain vehicle characteristics; however, the inclusion of model type indexes will limit the number of required entries by populating a number of pre-entered data fields based on one value.

The standardized template will also allow NHTSA to modify its existing compliance database to accept and import uniform data and automatically aggregate manufacturers' data. This will allow NHTSA to execute its regulatory obligations more efficiently and effectively. Overall, the template will help to ensure compliance with data requirements under EPCA/EISA and drastically reduce the industry and government's burden for reporting in accordance with the Paperwork Reduction Act.[1754] NHTSA made the template available through its docket as well as its PIC, and sought comment on the regulatory changes to the reporting process.

Comments on the template were received from the Auto Alliance, Global Automakers, Ford, Mercedes-Benz, Toyota, Volvo and Volkswagen. The Auto Alliance, Toyota, and Volkswagen opposed adopting the proposed template; however, Global Automakers agreed with the appropriateness of a standardized template that combines credit trading information with a data reporting template.[1755] Global Automakers also made two recommendations: (1) combine EPA's AB&T template with NHTSA's CAFE Projections Reporting Template to streamline reporting and reduce burden; and (2) add an FMY report requirement as an update to the MMY report submission.[1756]

Mercedes-Benz, Ford, and Volkswagen commented about data fields they believed were outdated, or not relevant to fuel economy testing or projecting fuel economy performance.[1757] Mercedes-Benz stated that some required data fields are not currently collected as a part of the fuel economy testing process, and their capture would require additional burden.[1758] Mercedes-Benz believes those data fields should be an optional requirement. Additionally, Mercedes-Benz recommended that NHTSA omit certain data fields, and stated that it would be helpful if NHTSA clarified its intention for the information in others.[1759] The specific data fields mentioned by

[1754] 44 U.S.C. 3501 *et seq.*
[1755] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Toyota, Detailed Comments, NHTSA-2018-0067-12150; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1756] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.
[1757] Daimler Mercedes, Detailed Comments, EPA-HQ-OAR-2018-0283-4182; Ford, Detailed Comments, NHTSA-2018-0067-11928; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1758] Daimler Mercedes, Detailed Comments, EPA-HQ-OAR-2018-0283-4182.
[1759] Daimler Mercedes, Detailed Comments, EPA-HQ-OAR-2018-0283-4182.

Mercedes-Benz are in Table 0-6Table 0-6. Ford stated that many of the data fields are outdated, have no bearing on compliance assessments, and are misaligned with the current reporting structure, which is dictated by model type index.[1760] Similarly, Volkswagen stated that the proposed reporting template is populated with many fields that do not immediately appear relevant to projecting CAFE performance, align with the existing requirements in 49 CFR 537.7, or seem relevant in the space of automotive technology.[1761]

Table 0-6 - Suggested Data Fields to Omit

Worksheet(s)	Data Field	Mercedes-Benz Recommendation
Footprint - DP, Footprint - IP, and Footprint - LT	Type of Overdrive	Omit
	Type of Torque Converter	
	Catalyst Usage	
	Electric Traction Motor	Provide Clarification
	Motor Controller	
	Battery Configuration	
	Electrical Charging System	
	Energy Storage Device	
Fuel Economy - DP, Fuel Economy - IP, and Fuel Economy - LT	Calibration	Omit
	Distributor Calibration	
	Choke Calibration	
	Basic Vehicle Frontal Area	
	Optional Equipment	

The Auto Alliance and Mercedes-Benz noted the differences in how NHTSA and EPA request data on A/C efficiency and off-cycle technologies. Mercedes-Benz highlighted the difficulty in predicting the projected sales production of the technologies, and the Auto Alliance cautioned that the number of reporting entries would increase by a factor of ten or more.[1762] The Auto Alliance stated its belief that the change in reporting requirements would cost its members more than $1 million in information technology changes and that the changes could not be completed prior to MY 2021.[1763] Likewise, Ford contended that an implementation date for MY 2019 is aggressive and does not provide manufacturers with adequate lead time.[1764]

The Auto Alliance emphasized that the templates lack common reporting standardization with submissions to EPA.[1765] The Auto Alliance, Global Automakers, Toyota, and Volvo all requested that NHTSA and EPA accept a single, common reporting format to satisfy reporting

[1760] Ford, Detailed Comments, NHTSA-2018-0067-11928.
[1761] Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1762] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Daimler Mercedes, Detailed Comments, EPA-HQ-OAR-2018-0283-4182.
[1763] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1764] Ford, Detailed Comments, NHTSA-2018-0067-11928.
[1765] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

for both agencies.[1766] Mercedes-Benz and Volkswagen requested stakeholder workshops to review the template with agency staff, with the former recommending that NHTSA host the workshops in partnership with EPA.[1767]

Ford requests that NHTSA re-examine the proposed required submission methods and reconsider current electronic submission methods.[1768] Ford expressed concern about the efficiency and security issues involved in submitting data on a CD through the mail containing confidential business information.[1769] Ford identified what it believes are better available avenues for submission, such as secured email or online portals like EPA's Central Data Exchange.[1770]

NHTSA disagrees with many of the manufacturers' assertions. Differences in EPA and NHTSA regulations prevent establishing a single reporting format for CAFE purposes. For example, EPA only needs early model year information for manufacturers' applications for certification required under 40 CFR 86.1843-01. Manufacturers submit a single application with extensive details for each certified vehicle within a test group (i.e., the certified vehicle represents all the vehicles within the test group with similar technologies and performance characteristics). In comparison, NHTSA's required early model year information is far less detailed and is aggregated for model types and compliance categories. However, NHTSA and EPA already share all the relevant CAFE FMY information pursuant to an interagency agreement. This arrangement not only benefits manufacturers but also reduces the burden on the Federal government. Since much of the required data in NHTSA's projections template is already contained in EPA final reports, manufacturers would not be required to generate additional information but simply to provide estimates along the way to finalizing the data. NHTSA plans to release a data matrix that maps data elements between the CAFE template and the EPA final CAFE reports. NHTSA will notify the public when the matrix will be available on its website. Consequently, there is no need to create an additional final report as an updated version of NHTSA's MMY report, as suggested by Global Automakers. Once NHTSA configures its CAFE database to accept the reporting template via file upload, the agency will be able to use the model type index data field to connect data values from the template to corresponding values in EPA's final CAFE report. Manufacturers should note that CAFE reports are estimated projections of the EPA final CAFE compliance data. Contrary to Mercedes concerns about the difficulty in predicting the projected sales production of the technologies, NHTSA only expects manufacturers to provide the most up-to-date information available 30 days before a report is required to be submitted to the Administrator as specified in 49 CFR Part 537.5(d). While manufacturer PMY reports may be limited in certain instances (excluding vehicles already in sales distribution), the MMY reports should be more inclusive and closer to

Commented [A429]: CHANGE AS SHOWN: Important to note distinction that this section refers to EPA's CAFE final reports, and not the EPA GHG performance reports which are part of the EPA Automotive Trends report, which EPA cites elsewhere.

[1766] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Toyota, Detailed Comments, NHTSA-2018-0067-12150; Volvo, Detailed Comments, NHTSA-2018-0067-12036.
[1767] Daimler Mercedes, Detailed Comments, EPA-HQ-OAR-2018-0283-4182; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1768] Ford, Detailed Comments, NHTSA-2018-0067-11928.
[1769] Ford, Detailed Comments, NHTSA-2018-0067-11928.
[1770] Ford, Detailed Comments, NHTSA-2018-0067-11928.

the final values reported to EPA. Manufacturers should also be submitting supplementary reports to NHTSA if they believe there will be significant differences between CAFE MMY reports and the EPA final reports.

Commenters also stated that the A/C and off-cycle information reported in the NHTSA template is inconsistent with the EPA ~~VERIFY~~EV-CIS.[1771] NHTSA notes that the inconsistency between the agencies is intentional and necessary. NHTSA's off-cycle and A/C information must be collected in greater detail than that reported to the EPA ~~VERIFY~~EV-CIS. NHTSA collects detailed information on A/C and off-cycle technologies for determining penetration rates of specific technologies in the market, as well as analyzing the types of technologies as equipped on specific model types. In comparison, EPA aggregates the data for calculating credits, which allows for combining the benefits for all the technologies equipped on a model type. NHTSA also will use the detailed information for public disclosure and for auditing purposes. However, NHTSA acknowledges the Auto Alliance's concerns about the burden placed on the industry for providing more detailed data and therefore will not require manufacturers to start using the templates for reporting until MY 2023. NHTSA also agrees with Ford that it is important to consider the issues of security and efficiency with respect to the submission of confidential information to the agency, and the agency will consider possible changes to its procedures relating to the receipt and handling of confidential information to ensure streamlined, secure, and efficient submission of confidential information, including CAFE reports.[1772]

Commented [A430]: CHANGE AS SHOWN: Correct name of the EPA database.

Secondly, NHTSA agrees with Mercedes-Benz and Volkswagen that workshops will aid in implementing the templates by providing instruction on how to complete them. NHTSA plans to host a workshop for manufacturers to discuss the implementation process. NHTSA believes finalizing the template in this rulemaking is important to address continuing concerns with reporting noncompliance (i.e., missing, incomplete, or inaccurate submissions) with the existing provisions in Part 537. Ultimately, establishing the new templates and holding educational workshops will be more effective in achieving industry compliance than imposing penalties on a case-by-case basis for failure to comply with reporting provisions.

Finally, NHTSA is also adopting changes to the proposed template in response to comments from Mercedes-Benz, Ford, and Volkswagen. NHTSA made changes to several of the data fields discussed by Mercedes-Benz. NHTSA does not agree with Mercedes-Benz's recommendation to omit the "Type of Overdrive" or "Type of Torque Converter" data fields; however, the agency does believe the proposed data to be inserted into those fields may be too specific for CAFE purposes. Therefore, the agency is finalizing a requirement that manufacturers identify whether vehicles are equipped with overdrive or a torque converter by selecting "Yes" or "No" from a dropdown list. The agency has also changed the "Calibration" field to "Other Calibration" to clarify the data being requested, and changed the "Auxiliary Emission Control Device" in the "Fuel Economy" worksheets to a dropdown that allows users to select multiple emission control systems. NHTSA believes that adding dropdown lists in the

[1771] See, e.g., Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1772] *See* 49 CFR part 512, 537.5.

template creates uniformity in the reported information and makes the information more relevant to current vehicles.

The agency agrees with the essence of Volkswagen's assertion that some of the required data fields may no longer be as common on contemporary vehicles, and therefore, may not apply to all manufacturers. As suggested by Mercedes-Benz, NHTSA has decided to make the "Catalyst Usage," "Distributor Calibration," "Choke Calibration," and "Other Calibration" data fields optional with a default value of "N/A." NHTSA does not agree with Mercedes-Benz's recommendation that NHTSA provide a better understanding of its intention for the information in certain data fields. "Electric Traction Motor, Motor Controller," "Battery Configuration," "Electrical Charging System," and "Energy Storage Device" are the data fields that characterize the basic powerplant for electric vehicles. Basic Engine, along with Carline and Transmission Class, make up a model type for light-duty vehicles. Therefore, those five fields are used to group vehicles by model type in accordance with EPA regulations. Fuel economy performance is calculated by Subconfiguration, which is a subset of a model type. As such, those five data fields are an integral part of grouping vehicles for fuel economy testing purposes in accordance with EPA regulations. NHTSA also does not agree with Volkswagen's assertion that the template is populated with many fields that do not appear relevant to projecting CAFE performance. As previously mentioned, many of the data fields are used to arrange vehicles into groups for calculating fuel economy performance in accordance with 49 CFR 537.7.

Furthermore, NHTSA has re-engineered the template in a few areas to include additional supporting data elements used in calculating other data fields required by Part 537. These fields may not directly align with the existing requirements in Part 537 but are necessary for validation purposes. For this reason, NHTSA is also finalizing its proposal in the NPRM to remove the optional provisions for reporting the data fields for determining the CAFE model type target standards, making the information mandatory in the template. Additional changes have been made to the template to improve fuel economy calculations. NHTSA edited the template to include the calculation procedure for alternative-fuel vehicles and corrected the test procedure adjustment (TPA) calculation to align the fleet average fuel economy calculation methodology with 40 CFR 600.510-12. Several expanded worksheets and functional features were also added to the template to improve the usability of the templates for manufacturers. These changes include modifications such as adding the estimated credits and a minimum domestic passenger shortfall calculator as the last fields to the "Summary" worksheet. Other functional changes include protecting users from changing the formatting or data validation in each cell and allowing columns to be widened by users.

(b) Standardized Credit Documents

A credit "[t]rade" is defined in 49 CFR 536.3 as "the receipt by NHTSA of an instruction from a credit holder to place its credits in the account of another credit holder."[1773] "Traded credits are moved from one credit holder to the recipient credit holder within the same compliance category for which the credits were originally earned. If a credit has been traded to

[1773] 49 CFR 536.3(b).

another credit holder and is subsequently traded back to the originating manufacturer, it will be deemed not to have been traded for compliance purposes."[1774] NHTSA does not administer trade negotiations between manufacturers and when a trade document is received the agreement must be issued jointly by the current credit holder and the receiving party.[1775] NHTSA does not settle contractual or payment issues between trading manufacturers.

NHTSA created its CAFE database to maintain credit accounts for manufacturers and to track all credit transactions. A credit account consists of a balance of credits in each compliance category and vintage held by the holder. While maintaining accurate credit records is essential, it has become a challenging task for the agency given the recent increase in credit transactions. Manufacturers have requested that NHTSA approve trade or transfer requests not only in response to end-of-model year shortfalls, but also, during the model year, when purchasing credits to bank.

To reduce the burden on all parties, encourage compliance, and facilitate quicker NHTSA credit transaction approval, the agency proposed in the NPRM to add a required template to standardize the information parties submit to NHTSA in reporting a credit transaction. Presently, manufacturers are inconsistent in submitting the information required by 49 CFR 536.8, creating difficulty for NHTSA in processing transactions. The template NHTSA proposed is a simple spreadsheet that trading parties fill out. When completed, parties will be able to click a button on the spreadsheet to generate a credit transaction summary and if applicable credit trade confirmation, the latter of which shall be signed by both trading entities. The credit trade confirmation serves as an acknowledgement that the parties have agreed to trade credits. The completed credit trade summary and a PDF copy of the signed trade confirmation must be submitted to NHTSA. Using the template simplifies CAFE compliance aspects of the credit trading process, and helps to ensure that trading parties follow the requirements for a credit transaction in 49 CFR 536.8(a).[1776]

Additionally, the credit trade confirmation includes an acknowledgement of the "error or fraud" provisions in 49 CFR 536.8(f)-(g), and the finality provision of 49 CFR 536.8(g). NHTSA sought comment on this approach, as well as on any changes to the template that may be necessary to facilitate manufacturer credit transaction requests. The agency uploaded the proposed template to the NHTSA's docket and the CAFE PIC site for manufacturers to download and review.

Only Global Automakers commented on the proposed credit transaction template, and Global Automakers supported adopting a uniform template. Global Automakers stated that, in theory, it agrees that a standardized template with credit trading information is appropriate, and a similar template is already in use for these types of reporting requirements by its members that could be integrated into the end of the year EPA final report. Global Automakers believes the use of similar templates have been well-established, and such a template could be implemented

[1774] *Id.*

[1775] *See* 49 CFR 536.8(a).

[1776] Submitting a properly completed template and accompanying transaction letter will satisfy the trading requirements in 49 CFR part 536.

across multiple agencies (i.e. NHTSA and EPA) with very little lag time in learning.[1777] No comments were received on the transaction letter generated by the template.

For the final rule, NHTSA is finalizing the proposed requirements for its credit templates to be incorporated into provisions for Part 536. NHTSA understands that manufacturers may be using similar credit reporting templates as part of their current business processes but has decided to adopt the template proposed in the NPRM. The NHTSA credit templates are an integral part of a long-range technology deployment that is already underway and will automate the NHTSA's CAFE database and web portal systems. When complete, the systems and portals will receive information directly from manufacturers and enable manufacturers, independently, to confirm credit trades and receive real-time credit balances. For this reason, diverging from the proposed templates for the final rule would impose unnecessary costs upon NHTSA. In the interest of accommodating the transition by manufacturers from other standardized templates, the agency will delay mandatory use of the CAFE credit template until January 1, 2021. Manufacturers may deviate from the generated language in the NHTSA credit trade confirmation by adding additional qualifications but, at a minimum, must include the core information generated by the template.

(c) Credit Transaction Information

Credit trading among entities commenced in the CAFE program starting in MY 2011.[1778] To date, NHTSA has received numerous credit trades from manufacturers but has only made limited information publicly available.[1779] As discussed earlier, NHTSA maintains an online CAFE database with manufacturer and fleetwide compliance information that includes year-by-year accounting of credit balances for each credit holder. While NHTSA maintains this database, the agency's regulations currently state that it does not publish information on individual transactions, and NHTSA has not previously required trading entities to submit information regarding the compensation (whether financial, or other items of value) manufacturers receive in exchange for credits.[1780, 1781] Thus, NHTSA's PIC offers sparse information to those looking to determine the value of a credit.

The lack of information regarding credit transactions means entities wishing to trade credits have little, if any, information to determine the value of the credits they seek to buy or sell. It is widely assumed that the civil penalty for noncompliance with CAFE standards largely determines the upper value of a credit, because it is logical to assume that manufacturers would not purchase credits if it cost less to pay civil penalties instead, but it is unknown how other factors affect the value. For example, a credit nearing the end of its five-model-year lifespan would theoretically be worth less than a credit within its full five-model-year lifespan. In the

[1777] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.
[1778] 49 CFR 536.6(c).
[1779] Manufacturers may generate credits, but non-manufacturers may also hold or trade credits. Thus, the word "entities" is used to refer to those that may be a party to a credit transaction.
[1780] 49 CFR 536.5(e)(1).
[1781] NHTSA understands that not all credits are exchanged for monetary compensation. The proposal that NHTSA is adopting in this final rule requires entities to report compensation exchanged for credits, and is not limited to reporting monetary compensation.

latter case, the credit holder would likely value the credit more, as it can be used for compliance purposes for a longer period of time.

In the interest of facilitating a transparent and efficient credit trading market, NHTSA stated in the NPRM that consideration is being given to modifying its regulations for credit trade information. NHTSA sought comment in the NPRM about the feasibility of requiring more information disclosure around trades, including price information, noting that neither the public, shareholders, competitors, nor even the agencies themselves know the price of credit transactions. More specifically, ~~the agencies~~NHTSA proposed requiring trading parties to submit information disclosing the identities of the parties to credit trades, the number of credits traded, and the amount of compensation exchanged for credits. Furthermore, NHTSA proposed that regulations would also permit the agency to publish information about specific transactions on the PIC.

Commented [A431]: CHANGE AS SHOWN: In the NPRM, NHTSA alone took comment on this issue, EPA did not.

NHTSA received comments from Volkswagen, Honda, Fiat Chrysler, Toyota, Global Automakers, the Auto Alliance, UCS, and from one private citizen, Mr. Jason Schwartz, regarding the scope of available credit information. All auto associations and manufacturers requested that NHTSA maintain the confidentiality of credit trades and transactions. The remaining commenters felt increased transparency would benefit the market.

Global Automakers, the Auto Alliance, Fiat Chrysler, and Volkswagen stated that credit trades are business-to-business, contain internal information and can involve both financial and non-financial compensation between parties.[1782] They stated credit transactions should be viewed as being similar to other competitive purchase agreements, which include non-disclosure terms and strict confidentiality with regard to cost and compensation.[1783] They contended that negotiations must remain confidential to protect the sensitive business practices for both the buyer and seller, and that revealing purchasing terms could result in a competitive disadvantage for both.[1784] Further, it was stated that certain transactions may not happen if they are publicized for fear of public criticism, making the program less efficient.[1785]

Honda added that disclosing trading terms may not be as simple as a spot purchase at a given price.[1786] Honda explained that it has undertaken a number of transactions for both CAFE and CO_2 credits, and there has been a range of complexity in these transactions due to numerous factors that are reflective of the marketplace, such as the volume of credits, compliance category, credit expiration date, a seller's compliance strategy, and even the CAFE penalty rate in effect at that time.[1787] In addition, Honda stated that automakers have a range of partnerships and

[1782] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1783] See, e.g., Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1784] See, e.g., Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1785] See, e.g., Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1786] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1787] Honda, Detailed Comments, NHTSA-2018-0067-11818.

cooperative agreements with their own competitors.[1788] Honda commented that credit transactions can be an offshoot of these broader relationships, and difficult to price separately and independently.[1789] Thus, Honda believes there may not be a reasonable, or even meaningful, presentation of "market" information in a transaction "price."[1790] Finally, Honda concluded by stating that information on pricing terms and business partner pairings is highly competitive and, if made public, could divulge to competitors a buyer's and/or seller's future compliance strategy.[1791] For these reasons, Honda believes it is appropriate to maintain the confidentiality of trade terms, pricing information, and of trading partner identification.[1792]

Fiat Chrysler stated that revealing credit transaction information would reveal highly confidential business information.[1793] It stated that credit transaction information may reveal the technology that is most valued by a company and the value of putting certain technology into a vehicle.[1794] It believed that credit trades are complex business transactions made at arm's length.[1795] As such, they may include monetary and non-monetary compensation, non-disclosure provisions, and other sensitive terms.[1796] Fiat Chrysler commented that publicizing such sensitive information could stifle the credit market and potentially result in uncompetitive outcomes, and could also decrease the efficiency in the credit trading marketplace.[1797] Fiat Chrysler further stated that the NPRM's justifications for requiring the disclosure of credit transaction information is unfounded and the government has no need of this information in the regular course of doing business.[1798]

The Auto Alliance, Honda, Toyota, and Volkswagen argued against NHTSA publishing credit movements each model year on its PIC. They stated that detailed credit banks by account holder are available to the public or entities wishing to engage in the credit market and that information is already sufficient.[1799] Global Automakers further contended that the agencies know which companies are trading and how those credits are being used, which is all that should be required for administering the program.[1800] The Auto Alliance argued that in private markets, trades and prices often are not made public; this privacy does not mean that the markets operate

[1788] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1789] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1790] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1791] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1792] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1793] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1794] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1795] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1796] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1797] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1798] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1799] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Honda, Detailed Comments, NHTSA-2018-0067-11818; Toyota, Detailed Comments, NHTSA-2018-0067-12150; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1800] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.

any less effectively, nor that the public at large does not benefit from the transactions that lower costs for all parties.[1801]

Volkswagen further commented that revealing confidential purchase terms has no precedent in the automotive industry. Volkswagen's position is that it does not disclose contract pricing for purchasing fuel saving technologies from suppliers, such as for turbochargers or battery packs. Therefore, Volkswagen does not believe it is appropriate to disclose the purchase price for CAFE credits.[1802]

Opposite views from those expressed by automobile manufacturers were received in the comments from UCS and Jason Schwartz. Both commenters strongly supported an increase in information regarding credit trading in the CAFE program.[1803] They argued that more information will allow manufacturers to make better informed decisions and lead to greater industry efficiency in general.[1804] UCS added that while the PIC does have some information, it is difficult to discern how the manufacturers are dividing credits to offset shortfalls.[1805] It requested NHTSA disclose at least as much information as EPA provides from its program, if not providing more information on transaction price and compliance category.[1806] Jason Schwartz had similar arguments for more transparency. Mr. Schwartz added that the agencies can assume that credits may be traded at prices similar to the civil penalty rate for noncompliance under the CAFE standards, but not knowing the actual prices greatly complicates the agencies' estimations of the costs of complying with the standards.[1807] Schwartz used several examples to explain and justify the need for making data on credit transactions, prices, and holdings publicly available to help the agency and the public assess the efficacy of the program.[1808] He also explained that such information will enable the smooth operation of the credit market by enabling credit buyers to better evaluate the value of credits and placing all players on equal informational footing which facilitates price discovery, and assists buyers and sellers in reaching terms.[1809] He added that regulators should require greater transparency to facilitate oversight.[1810] He asserted his belief that greater transparency in tracking transactions and credits helps regulators detect fraud, manipulation, market power, abuse, and to enforce compliance.[1811]

In response to these comments, NHTSA has decided not to share detailed information on credit transactions or the cost of individual credit transactions with the public. NHTSA agrees with manufacturers that revealing confidential purchase terms could result in a competitive

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[1801] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1802] Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1803] UCS, Detailed Comments, NHTSA-2018-0067-12039; Jason Schwartz, Detailed Comments, NHTSA-2018-0067-12162.
[1804] See, e.g., UCS, Detailed Comments, NHTSA-2018-0067-12039.
[1805] UCS, Detailed Comments, NHTSA-2018-0067-12039.
[1806] UCS, Detailed Comments, NHTSA-2018-0067-12039.
[1807] Jason Schwartz, Detailed Comments, NHTSA-2018-0067-12162.
[1808] Jason Schwartz, Detailed Comments, NHTSA-2018-0067-12162.
[1809] Jason Schwartz, Detailed Comments, NHTSA-2018-0067-12162.
[1810] Jason Schwartz, Detailed Comments, NHTSA-2018-0067-12162.
[1811] Jason Schwartz, Detailed Comments, NHTSA-2018-0067-12162.

disadvantage for both credit buyers and sellers, as well as harm to companies revealing highly confidential business materials. However, NHTSA believes that greater government oversight is needed over the CAFE credit market. NHTSA needs to understand more information surrounding trades, including costing information. As Honda recognized in its comments, NHTSA needs to understand the full range of complexity in transactions, monetary and non-monetary, in addition to the range of partnerships and cooperative agreements between credit account holders—which may impact the price of credit trades.[1812] NHTSA also believes, as mentioned by commenters, that disclosure of information concerning credit trades is important for facilitating government oversight for protecting against fraud, manipulation, market power, and abuse which may occur in the credit market.

NHTSA is adopting new reporting provisions in this final rule. Starting January 1, 2021, manufacturers will be required to submit all credit trade contracts, including costing and transactional information, to the agency. This information may be submitted confidentially, in accordance with 49 CFR part 512.[1813] NHTSA will use this information to determine the true cost of compliance for all manufacturers. This information will allow NHTSA to assess better the impact of its regulations on the industry, and provide more insightful information to use in developing future rulemakings. This confidential information will be held by secure electronic means in NHTSA's database systems. As for public information, NHTSA will include more information on the PIC on aggregated credit transactions, such as the combined flexibilities all manufacturers used for compliance as shown in Figure 0-6Figure 0-6, or information comparable to the credit information EPA makes available to the public. In the future, NHTSA will consider what information, if any, can be meaningfully shared with the public on credit transactional details or costs, while accounting for the concerns raised by the automotive industry.

(d) Precision of the CAFE Credit Adjustment Factor

EPCA, as amended by EISA, required the Secretary of Transportation to establish an adjustment factor to ensure total oil savings are preserved when manufacturers trade credits.[1814] The adjustment factor applies to credits traded between manufacturers and to credits transferred across a manufacturer's compliance fleets.

In establishing the adjustment factor, NHTSA did not specify the exact precision of the output of the equation in 49 CFR 536.4(b). NHTSA's standard practice has been round to the nearest four decimal places (e.g., 0.0001) for the adjustment factor. However, in the absence of a regulatory requirement, many manufacturers have contacted NHTSA for guidance, and NHTSA has had to correct several credit transaction requests. In some instances, manufacturers have had to revise signed credit trade documents and submit additional trade agreements to properly address credit shortfalls.

NHTSA proposed in the NPRM to add requirements to 49 CFR 536.4 specifying the precision of the adjustment factor by rounding to four decimal places (e.g., 0.0001). NHTSA has

[1812] Honda, Detailed Comments, NHTSA-2018-0067-11819.
[1813] *See also* 49 U.S.C. 32910(c).
[1814] 49 U.S.C. 32903(f)(1).

also included equations for the adjustment factor in its proposed credit transaction report template, mentioned above, with the same level of precision. NHTSA sought comment on this approach but received no comments, and therefore is finalizing this approach in this final rule.

(3) NHTSA Then Analyzes EPA-Certified CAFE Values for Compliance

After manufacturers complete certification testing and submit their final compliance values to EPA, EPA verifies the data and issues final CAFE reports to manufacturers and NHTSA. NHTSA then evaluates whether the manufacturers' compliance categories (i.e., domestic passenger car, imported passenger car, and light truck fleets) meet the applicable CAFE standards. NHTSA uses EPA-verified data to compare fleet average standards with actual fleet performance values in each compliance category. Each vehicle a manufacturer produces has a fuel economy target based on its footprint (footprint curves are discussed above in Section II.C), and each compliance category has a CAFE standard measured in miles per gallon (mpg). The manufacturer's fleet average CAFE standard is calculated based on the fuel economy target value and production volume of each vehicle model. The CAFE performance is calculated based on the compliance value and production volume of each vehicle model. A manufacturer complies with the CAFE standard if its fleet average performance is greater than or equal to its required standard, or if it is able to use available compliance flexibilities, described below in Section VIII.C.2.c. to resolve any shortfall.

If the average fuel economy level of the vehicles in a compliance category falls below the applicable fuel economy standard, NHTSA provides written notification to the manufacturer that it has not met that standard. The manufacturer is then required to confirm the shortfall and either submit a plan indicating how it will allocate existing credits, or if it does not have sufficient credits available in that fleet, how it will earn, transfer, and/or acquire credits, or pay the appropriate civil penalty. The manufacturer must submit a credit allocation plan or payment within 60 days of receiving agency notification.

NHTSA approves a credit allocation plan unless it finds the proposed credits are unavailable or that it is unlikely that the plan will result in the manufacturer earning sufficient credits to offset the projected shortfall. If a plan is approved, NHTSA revises the manufacturer's credit account accordingly. If a plan is rejected, NHTSA notifies the manufacturer and requests a revised plan or payment of the appropriate civil penalty. Similarly, if the manufacturer is delinquent in submitting a response within 60 days, NHTSA takes aution to collect a civil penalty. If NHTSA receives and approves a manufacturer's plan to carryback future earned credits within the following three years in order to comply with current regulatory obligations, NHTSA will defer levying civil penalties for noncompliance until the date(s) when the manufacturer's approved plan indicates that the credits will be earned or acquired to achieve compliance. If the manufacturer fails to acquire or earn sufficient credits by the plan dates, NHTSA will initiate noncompliance proceedings to collect civil penalties.[1815]

[1815] *See generally* 49 CFR part 536.

(4) Civil Penalties for Noncompliance

In the event that a manufacturer does not comply with a CAFE standard, EPCA provides that the manufacturer is potentially liable for a civil penalty.[1816] The manufacturer determines whether to use available credits to reduce or offset its potential penalty.[1817] This penalty rate is $5.50 for each tenth of a mpg that a manufacturer's average fuel economy falls short of the standard for a given model year multiplied by the total volume of those vehicles in the affected compliance category manufactured for that model year.[1818] A person (or manufacturer) that violates 49 U.S.C. 32911(a), including general CAFE violations other than those for failing to comply with CAFE standards (i.e., fuel economy labeling violations), is also liable to the United States Government for a civil penalty of not more than $42,530 for each violation. A separate violation occurs for each day the violation continues. All penalties are paid to the U.S. Treasury and not to NHTSA.[1819]

$$\begin{aligned} &Potential\ Civil\ Penalty \\ &\quad = \$5.50 \times (Avg.FE\ Performance - Avg.FE\ Standard) \times 10 \\ &\quad \times Total\ Production \end{aligned}$$

Since the inception of the CAFE program, the U.S. Treasury has collected a total of $969,978,472.50 in CAFE civil penalty payments. Generally, import manufacturers have paid significantly more in civil penalties than domestic manufacturers, with the majority of payments made by import manufacturers for passenger cars and not light trucks. Over the total program lifetime, import manufacturers paid a total of $969,520,032.50 in CAFE penalties while domestic manufacturers paid a total of $458,440.[1820]

Prior to the CAFE credit trade and transfer program, several manufacturers opted to pay civil penalties instead of complying with CAFE standards. Since NHTSA introduced trading and transferring, manufacturers have largely traded or transferred credits to achieve compliance, rather than paying civil penalties for noncompliance. NHTSA therefore assumes that buying and selling credits is a more cost-effective strategy for manufacturers than paying civil penalties, in

[1816] 49 U.S.C. 32911-12.

[1817] *See* 49 U.S.C. 32912.

[1818] NHTSA finalized a retaining the $5.50 civil penalty rate in an April 2018 NPRM. *See* 83 FR 13904 (Apr. 2, 2018).

[1819] 49 USC 32912(e) allows for fiscal year 2008 and each fiscal year thereafter, the total amount deposited in the general fund of the Treasury during the preceding fiscal year from fines, penalties, and other funds obtained through enforcement actions conducted pursuant to EISA and EPCA (including funds obtained under consent decrees), the Secretary of the Treasury, subject to the availability of appropriations, shall: (1) transfer 50 percent of such total amount to the account providing appropriations to the Secretary of Transportation for the administration of this chapter, which shall be used by the Secretary to support rulemaking under this chapter; and (2) transfer 50 percent of such total amount to the account providing appropriations to the Secretary of Transportation for the administration of this chapter, which shall be used by the Secretary to carry out a program to make grants to manufacturers for retooling, reequipping, or expanding existing manufacturing facilities in the United States to produce advanced technology vehicles and components.

[1820] These totals include penalties associated with all fleets for these manufacturers. For example, the total penalties paid by import manufacturers includes penalties associated with shortfalls in those manufacturers' domestic passenger car fleets.

part, because it seems logical that the price of a credit is directly related to the civil penalty rate and decreases as a credit's life diminishes.[1821] Prior to trading and transferring, on average, manufacturers paid $28,073,281.93 in civil penalty payments annually (a total of $814,125,176 from MYs 1982 to 2010). Since trading and transferring began, manufacturers now pay an average of $25,975,549.42 each model year. The agency notes that six manufacturers have paid civil penalties since 2011 totaling $155,853,296.50; Fiat Chrysler paid a civil penalty in MY 2016 equal to $77,268,720.50 for failing to meet the minimum domestic passenger car standard. NHTSA expects that, over the next several years, manufacturers will face challenges in avoiding paying further civil penalties as standards increase in stringency.

Commented [A432]: REVISE: Is there some technical analysis that could be cited to support this statement in the context of the 1.5% year-over-year stringency?

b) What Exemptions and Exclusions does NHTSA Allow?

(1) Emergency and Law Enforcement Vehicles

Under EPCA, manufacturers are allowed to exclude emergency vehicles, which include law enforcement vehicles, from their CAFE fleet.[1822] All manufacturers that produce emergency vehicles have historically done so. NHTSA did not propose any changes to this exclusion and therefore is retaining the provision without change for the final rule.

(2) Small Volume Manufacturers

Per 49 U.S.C. 32902(d), NHTSA established requirements for exempted small volume manufacturers in 49 CFR part 525, "Exemptions from Average Fuel Economy Standards." The small volume manufacturer exemption is available for any manufacturer whose projected or actual combined sales (whether in the U.S. or not) are fewer than 10,000 passenger automobiles in the model year two years before the model year for which the manufacturer seeks an exemption.[1823] The manufacturer must submit a petition with information stating that the applicable CAFE standard is more stringent than the maximum feasible average fuel economy level that the manufacturer can achieve.[1824] NHTSA must then issue by *Federal Register* notice, a proposed decision granting or denying the petition and inviting public comment.[1825] If the agency proposed to grant the petition, the notice includes an alternative average fuel economy standard for the passenger automobiles manufactured by the manufacturer.[1826] After conclusion of the public comment period, the agency publishes a final decision in the *Federal Register*.[1827] If the agency grants the petition, it establishes an alternative standard, which is the maximum feasible average fuel economy level for the manufacturers to which the alternative standard applies.[1828] NHTSA did not propose and is not making any changes to the small volume manufacturer provision or alternative standards regulations in this rulemaking.

[1821] *See* 49 CFR 536.4 for NHTSA's regulations regarding CAFE credits.
[1822] 49 U.S.C. 32902(e).
[1823] 49 CFR 525.5.
[1824] 49 CFR 525.7(h).
[1825] 49 CFR 525.8(c).
[1826] *Id.*
[1827] 49 CFR 525.8(e).
[1828] 49 U.S.C. 32902(d)(2); 49 CFR 525.8(e).

c) What Compliance Flexibilities and Incentives are Currently Available Under the CAFE Program and How do Manufacturers Use Them?

There are several compliance flexibilities and incentives that manufacturers can use to achieve compliance with CAFE standards beyond applying fuel economy-improving technologies. Some compliance flexibilities and incentives are statutorily mandated by Congress through EPCA and EISA. These specifically include program credits generated from overcompliance, including the ability to carry-forward, carryback, trade and transfer credits, and special fuel economy calculations for dual- and alternative-fueled vehicles (discussed in turn, below). However, 49 U.S.C. 32902(h) expressly prohibits NHTSA from considering the availability of statutorily established credits (either for building dual- or alternative-fueled vehicles or from accumulated transfers or traders) in setting the level of the standards. Thus, NHTSA may not raise CAFE standards because manufacturers have enough credits to meet higher standards, or because alternative fuel vehicles (including electric vehicles) are available to help manufacturers achieve compliance. ~~This is an important difference from EPA's authority under the CAA, which does not contain such a restriction, and which flexibility EPA has utilized in the past in determining appropriate levels of stringency for its program.~~

Commented [A433]: CHANGE AS SHOWN: Since this section is titled "compliance flexibilities under CAFE," it is not necessary to compare to EPA's program. Where relevant to explain what we are finalizing, EPA has drafted text to explain our final standards under the CAA, for example in the Justification section and in our Enhanced Flexibilities section.

Generating, trading, transferring, and applying CAFE credits is governed by statute.[1829] Program credits are generated when a vehicle manufacturer's fleet over-complies with its standard for a given model year, meaning its vehicle fleet achieved a higher corporate average fuel economy value than the amount required by the CAFE program for that fleet in that model year. Conversely, if the fleet average CAFE level does not meet the standard, the fleet would incur debits (also referred to as a shortfall). A manufacturer whose fleet generates a credit shortfall in a given model year can resolve its shortfall using any one or combination of several credits flexibilities, including credit carryback, credit carry-forward, credit transfers, and credit trades.

NHTSA also has promulgated compliance flexibilities and incentives consistent with EPCA's provisions regarding calculation of fuel economy levels for individual vehicles and for fleets.[1830] These compliance flexibilities and incentives, which were first adopted in the 2012 rule for MYs 2017 and later, include A/C efficiency improvement and off-cycle adjustments, and adjustments for advanced technologies in full-size pickup trucks, including adjustments for mild and strong hybrid electric full-size pickup trucks and performance-based incentives in full-size pickup trucks. The fuel consumption improvement benefits of these technologies measured by various testing methods can be used by manufacturers to increase the CAFE performance of their fleets.

Under NHTSA regulations, credit holders (including, but not limited to manufacturers) have credit accounts with NHTSA where they can, as outlined above, hold credits, and use them to achieve compliance with CAFE standards, by carrying forward, carrying back, or transferring credits across compliance categories. Manufacturers with excess credits in their accounts can

[1829] 49 U.S.C. 32903.
[1830] 49 U.S.C. 32904.

also trade credits to other manufacturers, who may use those credits to resolve a shortfall currently or in a future model year. A credit may also be cancelled before its expiration date if the credit holder so chooses. Traded and transferred credits are subject to an "adjustment factor" to ensure total oil savings are preserved.[1831] Credits earned before MY 2011 may not be traded or transferred.[1832]

Credit "carryback" means that manufacturers are able to use credits to offset a deficit that had accrued in a prior model year, while credit "carry-forward" means that manufacturers can bank credits and use them towards compliance in future model years. EPCA, as amended by EISA allows manufacturers to carryback credits for up to three model years, and to carry-forward credits for up to five model years.[1833] Credits expire the model year after which the credits may no longer be used to achieve compliance with fuel economy regulations.[1834] Manufacturers seeking to use carryback credits must have an approved carryback plan from NHTSA demonstrating their ability to earn sufficient credits in future MY's that can be carried back to resolve the current MY's credit shortfall. ~~EPA also follows these same limitations under its CO_2 program.~~[1835]

Credit "trading" refers to the ability of manufacturers or persons to sell credits to, or purchase credits from, one another. EISA gave NHTSA discretion to establish by regulation a CAFE credit trading program, to allow credits to be traded between vehicle manufacturers, now codified at 49 CFR part 536.[1836] EISA prohibited manufacturers from using traded credits to meet the minimum domestic passenger car CAFE standard.[1837]

As mentioned previously, the agencies sought comments in the NPRM on whether and how each agency's existing flexibilities and incentives might be amended, revised, or deleted to avoid the inefficiencies and market distortions as discussed earlier. NHTSA was concerned with the potential for unintended consequences. Specifically, comments were sought on the appropriate level of compliance flexibilities, including credit trading, in a program that is correctly designed to follow statutory direction to create maximum feasible fuel economy standards. Given that the credit trading program is discretionary under EISA, NHTSA also sought comments on whether the credit trading provisions in 49 CFR part 536 should cease to apply beginning in MY 2022. Comments were sought on whether to allow all incentive-based adjustments, except those that are mandated by statute, to expire, in addition to other possible simplifications to reduce market distortion, improve program transparency and accountability, and improve overall performance of the compliance programs.

[1831] 49 CFR 536.4(c).
[1832] 49 CFR 536.6(c).
[1833] 49 U.S.C. 32903(a).
[1834] 49 CFR 536.3(b).
~~[1835] As part of its MYs 2017-2025 CO_2 program final rulemaking, EPA did allow a one-time CO_2 carry-forward beyond five years, such that any credits generated from MYs 2010 through 2016 will be able to be used to comply with light-duty vehicle CO_2 standards at any time through MY 2021.~~
[1836] 49 U.S.C. 32903(f).
[1837] 49 U.S.C. 32903(f)(2).

The comments received from the public and NHTSA's responses to those comments are discussed below. A summary of all the flexibilities and incentives, and information on whether they were either retained or modified for the final rule, is presented in Table 0-1Table 0-1 through Table 0-4Table 0-4.

(1) Credit Carry-Forward and Back

Under the CAFE program, when the average fuel economy of a compliance fleet manufactured in a particular model year exceeds its applicable average fuel economy standard, the manufacturer earns credits.[1838] The credits may be applied to: (1) any of the 3 consecutive model years immediately before the model year for which the credits are earned; and (2) any of the 5 consecutive model years immediately after the model year for which the credits are earned. For example, a credit earned for exceeding model year 2017 standards will be usable for compliance purposes through and including the 2022 compliance model year. NHTSA sought no comments or proposed changes to any of the aspects of its lifespan for CAFE credits because of the existing statutory limitation set forth by Congress. The public offered no comments on such flexibilities under the CAFE program.

Commented [A434]: CHANGE AS SHOWN: Note that EPA did request comment on extending credit carry-forward under the GHG program, and we did received comments, so it's important to clarify that this statement is in reference to the CAFE program only.

(2) Credit Trading

All commenters responding to the NPRM on this issue favored retaining the existing CAFE credit trading program. Comments on credit trading were received from Volkswagen, Honda, General Motors, CARB, BorgWarner, Jaguar Land Rover, Fiat Chrysler, Global Automakers, the Auto Alliance, the Institute for Policy Integrity, Toyota, and academic commenters, Jeremy Michalek and Jason Schwartz. No comments were received supporting the idea of changing the existing credit trading program.

In general, manufacturers' comments centered around problems in predicting whether consumers will purchase the fuel efficient vehicles necessary for manufacturers to meet their compliance obligations. They stated that continuing the credit trading program allows manufacturers to address uncertainty in the market better.[1839] The Auto Alliance, Volkswagen, Fiat Chrysler, and Honda commented that credit flexibilities allow manufacturers to comply with the program even when faced with market uncertainties.[1840] Honda stated that credit trading allows the government to set reasonable standards without fear of having to cater to the least-capable manufacturer.[1841] Jaguar Land Rover stated the removal of NHTSA's credit trading programs would increase and intensify the dis-harmonization between the CO_2 and CAFE programs.[1842]

[1838] 49 U.S.C. 32903 and 49 CFR 536.
[1839] See, e.g., Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1840] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583-22; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1841] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1842] Jaguar Land Rover, Detailed Comments, NHTSA-2018-0067-11916-9.

Global Automakers, Fiat Chrysler, Jason Schwartz, and Jeremy Michalek each commented that the credit trading program allows for a more efficient compliance process given that more fuel-efficient manufacturers can sell their credits to manufacturers who fall short.[1843] These commenters and BorgWarner stated that the program lowers the overall cost of reducing fuel consumption.[1844] Likewise, Jaguar Land Rover, Fiat Chrysler, and General Motors argued compliance flexibilities, like trading, increase the ability to achieve higher fuel economy and reduced CO_2 emissions. They found that the credit trading flexibility allows them to invest more money in technologies that will lead to future increases in their fuel economy.[1845] Similarly, CARB argued credit flexibilities have been shown to be successful in reducing emissions and spurring innovation. It saw no reason to remove a successful program.[1846]

Fiat Chrysler stated that credit trading allows manufacturers to provide more choices for consumers since manufacturers are not required to meet the standard exactly, but rather, they can purchase traded credits and then provide vehicles the public is demanding while still complying with fleet average standards.[1847] They stated that this leads to the overall compliance of the U.S. fleet while allowing for more consumer choices. They further added that if the program is removed, manufacturers that currently generate credits from their fuel-efficient fleet may find it more profitable to begin producing less fuel-efficient vehicles, perhaps even halting the current improvements in fuel efficiency across the industry.[1848]

Honda commented that regulatory flexibilities, such as credit trading, built into the CO_2 and CAFE programs have become critical elements to the programs' success, especially in the face of product cadences with uneven sales that do not always match compliance obligations.[1849] General Motors stated its belief that program flexibilities will continue to play an increasingly important role in reducing CO_2 emissions and increasing fuel economy through technologies and innovations.[1850] CARB stated that existing flexibilities create consistency in compliance planning for automakers for model years in the existing program.[1851] Fiat Chrysler added that each of the CAFE and CO_2 programmatic tools and flexibilities should be retained, improved and strengthened. Fiat Chrysler opined that this is a chance for the agencies to make better policies that work more efficiently and as intended, and cautioned that eliminating them now could have the serious negative impact of making the standards more stringent and costlier for manufacturers.[1852]

[1843] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Jason Schwartz, Detailed Comments, NHTSA-2018-0067-12162; Jeremy Michalek, Detailed Comments, NHTSA-2018-0067-11903.
[1844] BorgWarner, Detailed Comments, NHTSA-2018-0067-11895.
[1845] Jaguar Land Rover, Detailed Comments, NHTSA-2018-0067-11916; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; General Motors, Detailed Comments, NHTSA-2018-0067-11858.
[1846] CARB, Detailed Comments, NHTSA-2018-0067-11873.
[1847] General Motors, Detailed Comments, NHTSA-2018-0067-11943.
[1848] General Motors, Detailed Comments, NHTSA-2018-0067-11943.
[1849] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1850] General Motors, Detailed Comments, NHTSA-2018-0067-11858.
[1851] CARB, Detailed Comments, NHTSA-2018-0067-11873.
[1852] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.

NHTSA is not making changes to its credit trading provisions in the final rule. NHTSA sought comments on removing the optional credit trading program to explore public views on market distortions or windfalls that occur as a result of the credit trading program. However, commenters consistently opined that removing existing flexibilities might result in manufacturers not building certain types of vehicles. This could adversely impact compliance plans over multiple model years. NHTSA concurs with those views, and since this final rule adopts CAFE standards that continuously increase through MY 2026, understands the importance of allowing for credit trading to provide additional means of achieving compliance for manufacturers who face varying degrees of difficulty in achieving the standards the agencies are finalizing today. *With increasing* standards, credit trading flexibilities help to compensate for an uneven sales mix of vehicle types and to aid with compliance planning. ~~EPA final sales volumes, as presented earlier, show a shift in consumers purchasing more small SUVs subject to passenger car standards, and these vehicles are less fuel efficient than the compact and mid-sized passenger cars that previously dominated the market.~~ The need to ensure consumer choice is adequately considered drives the need for ~~the agency~~ NHTSA to provide credit trading flexibility to manufacturers. For example, even with increasing standards, a manufacturer could continue to sell certain types of vehicles with lower mpg performance over a longer period of time to satisfy its consumers by purchasing credits or carrying credits back from future model years to address the mpg fleet shortages caused by these vehicles, before ultimately having to introduce more fuel-efficient technologies. NHTSA believes that these types of scenarios are consistent with the purpose of the CAFE credit program, as adopted by Congress.

Commented [A435]: CHANGE AS SHOWN: This is not an accurate statement based on the EPA Trends reports, and its not clear what point is being made since the example's car SUVs and passenger cars share the same footprint standards curves. While car SUVs have seen growth, there has been much more growth in truck SUVs. Between 2012 and 2017 Car SUVs increased market share from 9.4% to 11.5%, while Truck SUVs increased from 20.6% to 31.8%. For the SUVs that can qualify as either cars or trucks, the truck curves are significantly more lenient. The statement that compact cars ever "dominated" the market seems inaccurate as well.

(3) Credits Transferring

Credit "transfer" means the ability of manufacturers to move credits from their passenger car fleet to their light truck fleet, or vice versa. As part of the EISA amendments to EPCA, NHTSA was required to establish by regulation a CAFE credit transferring program, now codified at 49 CFR part 536, to allow a manufacturer to transfer credits between its car and truck fleets to achieve compliance with the standards.[1853] For example, credits earned by overcompliance with a manufacturer's car fleet average standard may be used to offset debits incurred because of that manufacturer's failed to meet the truck fleet average standard in a given year. However, EISA imposed a cap on the amount by which a manufacturer could raise its CAFE performance through transferred credits: 1 mpg for MYs 2011-2013; 1.5 mpg for MYs 2014-2017; and 2 mpg for MYs 2018 and beyond.[1854] These statutory limits will continue to apply to the determination of compliance with CAFE standards. EISA also prohibits the use of transferred credits to meet the minimum domestic passenger car fleet CAFE standard.[1855]

In the NPRM, NHTSA responded to the 2016 petition for rulemaking from the Auto Alliance and Global Automakers (Alliance/Global or Petitioners) asking to amend the regulatory definition of "transfer" as it pertains to compliance flexibilities.[1856] In particular,

[1853] *See* 49 U.S.C. 32903(g)(1).
[1854] 49 U.S.C. 32903(g)(3).
[1855] 49 U.S.C. 32903(g)(4).
[1856] Auto Alliance and Global Automakers Petition for Direct Final Rule with Regard to

Alliance/Global requested that NHTSA add text to the definition of "transfer" stating that the statutory transfer cap in 49 U.S.C. 32903(g)(3) applies when the credits are transferred. Alliance/Global assert that adding this text to the definition is consistent with NHTSA's prior position on this issue in the MYs 2012-2016 final rule, in which NHTSA stated:

> *NHTSA interprets EISA not to prohibit the banking of transferred credits for use in later model years. Thus, NHTSA believes that the language of EISA may be read to allow manufacturers to transfer credits from one fleet that has an excess number of credits, within the limits specified, to another fleet that may also have excess credits instead of transferring only to a fleet that has a credit shortfall. This would mean that a manufacturer could transfer a certain number of credits each year and bank them, and then the credits could be carried forward or back 'without limit' later if and when a shortfall ever occurred in that same fleet.*[1857]

NHTSA clarified in the NPRM, based upon a previous interpretation, that the transfer cap from EISA does not limit how many credits may be *transferred* in a given model year, but it does limit the *application* of transferred credits to a compliance category in a model year.[1858] The interpretation concludes by stating that, "Thus, manufacturers may transfer as many credits into a compliance category as they wish, but transferred credits may not increase a manufacturer's CAFE level beyond the statutory limits."[1859]

NHTSA maintains its views that the transfer caps in 49 U.S.C. 32903(g)(3) are properly read to apply to the application of credits. As NHTSA explained in the NPRM, it understands that the language in the MYs 2012-2016 final rule could be read to suggest that the transfer cap applies at the time credits are transferred. However, NHTSA believes its existing interpretation — that the transfer cap applies at the time the credits are used — is a more appropriate, plain language reading of the statute. While manufacturers have approached NHTSA with various interpretations that would essentially allow them to circumvent the EISA transfer cap, NHTSA believes such interpretations are improper because they would not give effect to the statutory transfer cap. Therefore, NHTSA proposed in the NPRM to deny Alliance/Global's petition to revise the definition of "transfer" in 49 CFR 536.3, and is now finalizing that denial.

In response to the tentative denial of the petition above in the NPRM, comments were received from the Global Automakers and Toyota asking NHTSA to reconsider applying the transfer cap of 2.0 mpg per year when credits are transferred rather than when they are

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Various Aspects of the Corporate Average Fuel Economy Program and the Greenhouse Gas Program (June 20, 2016) at 13, *available at https://www.epa.gov/sites/production/files/2016-09/documents/petition_to_epa_from_auto_alliance_and_global_automakers.pdf* [hereinafter Alliance/Global Petition].

[1857] 75 FR 25666 (May 7, 2010).

[1858] See, letter from O. Kevin Vincent, Chief Counsel, NHTSA to Tom Stricker, Toyota (July 5, 2011), *available at* https://isearch.nhtsa.gov/files/10-004142%20--%20Toyota%20CAFE%20credit%20transfer%20banking%20--%205%20Jul%2011%20final%20for%20signature.htm (last accessed Apr. 18, 2018).

[1859] *Id.*

applied.[1860] They reiterated that imposing the cap when applying the credits is overly burdensome, but did not provide any new information that has persuaded NHTSA to change its view that the petition should be denied. The Auto Alliance also stated that NHTSA should revise its definition of "transfer" to be more consistent with EPA.[1861]

Other more general comments to the NPRM were also received from Walter Kreucher, Jeremy Michalek, Global Automakers, the Auto Alliance, and Toyota, regarding the use of the credit transfer flexibility. These commenters generally appreciated the transfer flexibility for its ability to reduce compliance costs.[1862] More specifically, Walter Kreucher commented that the ability to transfer credits between compliance categories was beneficial for manufacturers and allowed for efficiency in the markets and reduce compliance costs.[1863]

For the final rule, NHTSA is not making any changes to the existing provisions regarding transferring credits. NHTSA's position remains unchanged that the transfer cap in 49 U.S.C. 32903(g)(1) clearly limits the amount of performance increase for a manufacturer's fleet that fails to achieve the prescribed standards. The same statutory provision prevents NHTSA from changing its definition for transfer to be consistent with EPA. Consequently, NHTSA is not changing its definition or its previous interpretation that the application of transfer caps applies at the time the credits are used and not when transferred. Therefore, NHTSA is finalizing its decision to deny the Auto Alliance and Global Automakers petition.

(4) Minimum Domestic Passenger Car Standard

EPCA, as amended by EISA, addresses the minimum domestic passenger car standard (MDPCS), clearly stating that any manufacturer's domestically-manufactured passenger car fleet must meet the greater of either 27.5 mpg on average, or 92 percent of the average fuel economy projected by the Secretary for the combined domestic and non-domestic passenger automobile fleets manufactured for sale in the U.S. by all manufacturers in the model year, which projection shall be published in the Federal Register when the standard for that model year is promulgated in accordance with 49 U.S.C. 32902(b).[1864] Since that requirement was added to the statute, the "92 percent" has always been greater than 27.5 mpg. NHTSA published the 92 percent MDPCS for MYs 2017–2025 at 49 CFR 531.5(d) as part of the 2012 final rule. 49 CFR 531.5(e) explains that the published MDPCS for MYs 2022–2025 are not final and may change when NHTSA sets standards for those model years. This is consistent with the statutory requirement that the 92 percent standards must be determined at the time an overall passenger car standard is promulgated and published in the Federal Register.[1865] Any time NHTSA establishes or changes a passenger car standard for a model year, the MDPCS for that model year must also be

[1860] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Toyota, Detailed Comments, NHTSA-2018-0067-12150.
[1861] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1862] *See, e.g.*, Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.
[1863] Walter Kreucher, Detailed Comments, NHTSA-2018-0067-0444.
[1864] 49 U.S.C. 32902(b)(4).
[1865] 49 U.S.C. 32904(b)(4)(B).

evaluated or re-evaluated and established accordingly. Thus, this final rule establishes the applicable MDPCS for MYs 2021-2026.

The 2016 Alliance/Global petition for rulemaking asked NHTSA to retroactively revise the 92 percent MDPCS for MYs 2012–2016 "to reflect 92 percent of the required average passenger car standard taking into account the fleet mix as it actually occurred, rather than what was forecast." The petitioners claimed that doing so would be "fully consistent with the statute."[1866] NHTSA acknowledged in the NPRM that determining the 92 percent value ahead of the model year to which it applies, based on the information then available to the agency, results in a different mpg number than if NHTSA determined the 92 percent value based on the information available at the end of the model year in question. NHTSA further acknowledged that determining the 92 percent value in advance can make the MDPCS more stringent than it could be if it were determined at the end of the model year, if manufacturers end up producing more larger-footprint passenger cars than NHTSA originally anticipated.

Accordingly, NHTSA sought comments in the NPRM on the request made by Alliance/Global recognizing the uncertainty inherent in projecting specific mpg values far into the future. NHTSA also stated that it is possible to define the mpg values associated with a CAFE standard (i.e., the footprint curve) as a range rather than as a single number. If NHTSA took that approach, 92 percent of that "standard" would also, necessarily, be a range.

NHTSA received several comments regarding the minimum domestic passenger car standard (MDPCS). Commenters included Walter Kreucher, a joint submission from the States of California et al. and the Cities of Oakland et al., Fiat Chrysler, and the Auto Alliance. Walter Kreucher asserted that NHTSA must continue to allow and even expand flexibilities to allow manufacturers to meet the MDPCS. He suggested applying retroactive air conditioning credits to help manufacturers become compliant.[1867] Fiat Chrysler and the Auto Alliance requested NHTSA establish a MDPCS range rather than a single value and then recalculate that range to a value at the end of each model year. This will lead to a more accurate MDPCS value, which they believe are currently set too high.[1868] The joint submission from the States of California et al. and the Cities of Oakland et al. did not believe the minimum domestic passenger car standard needed revising. They stated EPCA does not allow for an interpretation of a range and a projected minimum set value was how the statute was written.[1869]

[Text Forthcoming]

[1866] Alliance/Global Petition at 5, 17-18.
[1867] Walter Kreucher, Detailed Comments, NHTSA-2018-0067-0444.
[1868] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1869] Joint submission from States of California et al. and the Cities of Oakland et al., Detailed Comments, NHTSA-2018-0067-11735.

(5) Fuel Savings Adjustment Factor

Under NHTSA's credit trading regulations, a fuel savings adjustment factor is applied when trading occurs between manufacturers or when a manufacturer transfers credits between its fleets, but not when a manufacturer carries credits forward or carries back credits within the same fleet.[1870] The Alliance/Global requested in their 2016 petition that NHTSA require manufacturers to apply the fuel savings adjustment factor when credits are carried forward or carried back within the same fleet, including for existing, unused credits.

Per EISA, total oil savings must be preserved in NHTSA's credit trading program.[1871] The statutory provisions for credit transferring within a manufacturer's fleet do not explicitly include the same requirement; however, NHTSA prescribed a fuel savings adjustment factor that applies to both credit trades between manufacturers and credit transfers between a manufacturer's compliance fleets.[1872,1873]

When NHTSA initially considered the preservation of oil savings, the agency explained how one credit is not necessarily equal to another. For example, the fuel savings lost if the average fuel economy of a manufacturer falls one-tenth of an mpg below the level of a relatively low standard are greater than the average fuel savings gained by raising the average fuel economy of a manufacturer one-tenth of a mpg above the level of a relatively high CAFE standard.[1874] The effect of applying the adjustment factor is to increase the numerical value of credits for compliance accounting that are earned for exceeding a CAFE standard, that are applied to a compliance category with a higher CAFE standard. Likewise, the adjustment factor has the effect of decreasing the numerical value of credits for compliance accounting that are earned for exceeding a CAFE standard, that are applied to a compliance category with a lower CAFE standard. While applying the adjustment factor impacts the compliance accounting value of credits which are denominated in miles per gallon, the adjustment maintains the real world value of credits from the perspective of the actual amount of fuel consumed or saved.

Alliance/Global stated, in its 2016 petition, that while carry-forward and carryback credits have been used for many years, the CAFE standards did not change during the Congressional CAFE freeze, meaning credits earned during those years were associated with the same amount of fuel savings from year to year.[1875] Alliance/Global suggest that because there is

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[1870] *See* 49 CFR 536.4(c).
[1871] 49 U.S.C. 32903(f)(1).
[1872] 49 U.S.C. 32903(g).
[1873] *See* 49 CFR 536.5; *see also* 74 FR 14430 (Mar. 30, 2009) (Per NHTSA's final rule for MY 2011 Average Fuel Economy Standards for Passenger Cars and Light Trucks, "There is no other clear expression of congressional intent in the text of the statute suggesting that NHTSA would have authority to adjust transferred credits, even in the interest of preserving oil savings. However, the goal of the CAFE program is energy conservation; ultimately, the U.S. would reap a greater benefit from ensuring that fuel oil savings are preserved for both trades and transfers. Furthermore, accounting for traded credits differently than for transferred credits does add unnecessary burden on program enforcement. Thus, NHTSA will adjust credits both when they are traded and when they are transferred so that no loss in fuel savings occurs.").
[1874] 74 FR 14432 (Mar. 30, 2009).
[1875] Alliance/Global Petition at 10.

no longer a Congressional CAFE freeze, NHTSA should apply the adjustment factor when moving credits within a manufacturer's fleet (i.e. carry-forward or carryback) beginning retroactively in MY 2011.[1876]

In the NPRM, NHTSA tentatively denied Alliance/Global's request to apply the fuel savings adjustment factor to credits that are carried forward or carried back within the same fleet to the extent that the request would impact credits carried forward or back retroactively within manufacturers' compliance fleets (i.e., credits that were generated prior to MY 2021 when the standards set by this rule first apply). NHTSA tentatively determined that applying the adjustment factor to credits earned in prior model years would be inequitable to apply retroactively. There would be an advantage for manufacturers carrying credits into future model years with higher CAFE standards. Manufacturers have historically planned compliance strategies based, at least in part, on the existing rules for how credits could be carried forward and back, including the lack of an adjustment factor when credits are carried forward or back within the same fleet. Thus, retroactively requiring an adjustment factor could disadvantage certain manufacturers without credits, and result in windfalls for other manufacturers.

To explore the impact on future model years, NHTSA sought additional comments in the NPRM on the feasibility of applying the fuel savings adjustment factor to credits carried forwards or back starting in MY 2021. Global Automakers submitted new comments arguing that the application of fuel savings adjustment factors to credits carried forward or back would not result in a credit windfall. They believed this practice would ensure that credits have a consistent value over time.[1877]

Comments from Global Automakers provided no further justification that would persuade NHTSA to consider changing its position on denying the application of the adjustment factor to carry-forward and carryback credits beginning with MY 2011. NHTSA continues to be concerned about the inequitable outcome retroactive adjustments would have on the credit market. Therefore, NHTSA is finalizing its decision to deny the Alliance/Global request to apply the adjustment factor to credits carried forward or carried back within a compliance category retroactively beginning as early as MY 2011.

Congress expressly required that DOT establish a credit "transferring" regulation, to allow individual manufacturers to move credits from one of their fleets to another (e.g., using a credit earned for exceeding the light truck standard for compliance with the domestic passenger car standard). Congress also gave DOT discretion to establish a credit "trading" regulation so that credits may be bought and sold between manufacturers.[1878] Congress specified that trading was for earned credits "to be sold to manufacturers whose automobiles fail to achieve the prescribed standards such that the total oil savings associated with manufacturers that exceed the prescribed standards are preserved."[1879] NHTSA established 49 CFR part 536 believing it was consistent with the statute for transferred credits to be subject to the same "adjustment factor" to

[1876] Alliance/Global Petition at 4.
[1877] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.
[1878] 49 U.S.C. 32903(f).
[1879] 49 U.S.C. 32903(f)(1).

ensure total oil savings are preserved.[1880] NHTSA believed that no further application of the adjustment factor to other credit flexibilities would be appropriate at that time. NHTSA sought comments in the NPRM to explore the consequences associated with applying the adjustment factor to credits carried forward and back starting in MY 2021, but no further insight was gained from the comments received. Therefore, NHTSA is retaining its existing requirements for the adjustment factor to be applied to transferred and traded credits only. NHTSA will continue considering potential application of the adjustment factor for all types of credit flexibilities in the future, and may consider regulatory changes in subsequent rulemakings.

(6) VMT Estimates for Fuel Savings Adjustment Factor

NHTSA uses the vehicle miles traveled (VMT) estimate as part of its fuel savings adjustment equation to ensure that when traded or transferred credits are used, fuel economy credits are adjusted to ensure fuel oil savings is preserved.[1881] For MYs 2017-2025, NHTSA finalized VMT values of 195,264 miles for passenger car credits, and 225,865 miles for light truck credits.[1882] These VMT estimates harmonized with those used in EPA's CO_2 program. For MYs 2011-2016, NHTSA estimated different VMTs by model year.

In the NPRM, NHTSA explained that Alliance/Global requested in their 2016 petition that NHTSA apply fixed VMT estimates to the fuel savings adjustment factor for MYs 2011-2016 similar to how NHTSA handled VMT values for MYs 2017-2025.[1883] NHTSA rejected a similar request from the Auto Alliance in the MY 2017 and later rulemaking, citing lack of scope, and expressing concern about the potential loss of fuel savings.[1884]

The Alliance/Global argued that data from MYs 2011-2016 demonstrate that no fuel savings would have been lost, as was NHTSA's concern.[1885] Alliance/Global asserted that by not revising the MY 2012-2016 VMT estimates, credits earned during that timeframe were undervalued.[1886] Therefore, Alliance/Global argued that NHTSA should retroactively revise its VMT estimates to "reflect better the real-world fuel economy results."[1887]

Such retroactive adjustments could have unfair adverse effects upon manufacturers for decisions they made based on the regulations as they existed at the time. ~~As Alliance/Global acknowledged, adjusting VMT estimates would disproportionately affect manufacturers that have a credit deficit and were part of EPA's Temporary Lead-time Allowance Alternative Standards (TLAAS).[1888] The TLAAS program sunsets for MYs 2021 and later.~~ Given that some manufacturers would be disproportionately affected were NHTSA to adopt Alliance/Global's

Commented [A436]: CHANGE AS SHOWN: EPA does not agree with the Alliance/Global's petition assertion that TLAAS is connected to this issue since the EPA program already holds VMT constant across MYs. This is a CAFE only issue.

[1880] 74 FR 14196, 14434 (Mar. 30, 2009).
[1881] *See* 49 CFR 536.4(c).
[1882] 77 FR 63130 (Oct. 15, 2012).
[1883] Alliance/Global Petition at 5, 11.
[1884] *Id.*
[1885] Alliance/Global Petition at 11.
[1886] *Id.*
[1887] Alliance/Global Petition at 11.
~~[1888] *Id.* at 11 n.12.~~

proposal, in the NPRM, NHTSA tentatively denied Alliance/Global's request to change the agency's VMT schedules for MYs 2011-2016 retroactively. ~~Alliance/Global's suggestion that a TLAAS manufacturer should be allowed to elect either approach does not change the fact that manufacturers in the TLAAS program made production decisions based on the regulations as understood at the time.~~[1880] NHTSA sought comments on the Alliance/Global requests in the NPRM.

However, no further comments were received on this issue in response to the NPRM. Therefore, NHTSA is finalizing its decision to deny the Alliance/Global request to modify the VMT schedules for MYs 2011-2016.

(7) Special Fuel Economy Calculations for Dual and Alternative Fueled Vehicles

As discussed at length in prior rulemakings, EPCA, as amended by EISA, encouraged manufacturers to build alternative-fueled and dual- (or flexible-) fueled vehicles by providing special fuel economy calculations for "dedicated" (that is, 100 percent) alternative fueled vehicles and "dual-fueled" (that is, capable of running on either the alternative fuel or gasoline/diesel) vehicles.

Dedicated alternative-fuel automobiles include electric, fuel cell, and compressed natural gas vehicles, among others. The statutory provisions for dedicated alternative fuel vehicles in 49 U.S.C. 32905(a) state that the fuel economy of any dedicated automobile manufactured after MY 1992 shall be measured "based on the fuel content of the alternative fuel used to operate the automobile. A gallon of liquid alternative fuel used to operate a dedicated automobile is deemed to contain 0.15 gallon of fuel." Under EPCA, for dedicated alternative fuel vehicles, there are no limits or phase-out for this special fuel economy calculation, unlike for duel-fueled vehicles, as discussed below.

EPCA's statutory incentive for dual-fueled vehicles at 49 U.S.C. 32906 and the measurement methodology for dual-fueled vehicles at 49 U.S.C. 32905(b) and (d) expire after MY 2019; therefore, NHTSA had to examine the future of these provisions in the MY 2017 and later CAFE rulemaking. NHTSA and EPA concluded that it would be inappropriate to measure duel-fueled vehicles' fuel economy like that of conventional gasoline vehicles with no recognition of their alternative fuel capability, which would be contrary to the intent of EPCA/EISA. The agencies determined that for MY 2020 and later vehicles, the general statutory provisions authorizing EPA to establish testing and calculation procedures provide discretion to set the CAFE calculation procedures for those vehicles. The methodology for EPA's approach is outlined in the 2012 final rule for MYs 2017 and later at 77 FR 63128 (Oct. 15, 2012). In the NPRM, NHTSA sought comments on that current approach.

NHTSA received comments from the Coalition for Renewable Natural Gas, NGV America, the American Gas Association, the American Public Gas Association, CARB, Ingevity

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[1880] ~~*See id.* at 11-12 n.12.~~

Corporation, Fuel Freedom Foundation, UCS, National Farmers Union, Indiana Corn Growers Association, Volkswagen, and a joint submission from Ariel Corp. and VNG.co.

Fuel Freedom Foundation and the National Farmers Union asserted that the agencies should continue offering incentives for emerging technology vehicles including natural gas vehicles, internal combustion engine (ICE) vehicles that encourage renewable fuel use, electric and hydrogen fuel cell vehicles, flex-fuel vehicles (FFVs), and dedicated high-octane vehicles designed for compatibility with mid-level ethanol blends.[1890]

Indiana Corn Growers Association and Fuel Freedom Foundation specified that FFVs, as well as vehicles that run on mid-level ethanol blends, should receive credit for the petroleum reduction value.[1891] For vehicles using higher-ethanol blends, these commenters stated that the agencies should establish more accurate petroleum equivalency factors for the proportion of ethanol versus gas.[1892] Clean Fuels Development Coalition requested credits for producing "Engines Optimized for High-Octane" be reinstated.[1893] Volkswagen made the same request and added that a pathway to higher-octane fuel is important to it.[1894]

Ariel Corp. and VNG.co, the Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association commented that the agencies should expand incentives for natural gas vehicles in the light-duty sector especially for pick-up trucks, work vans, and sport utility vehicles.[1895] They argued that current incentives are not strong enough to induce manufacturers to produce natural gas vehicles. They further requested that the market penetration rates be removed for light-duty trucks.[1896]

The Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association argued that an AMFA factor of 0.15 is low and because some natural gas vehicles can operate at 100 percent natural gas, a higher fuel economy credit is justified. They further supported a permanent use of the 0.15 factor for dual-fuel vehicles.[1897] Similarly, Ingevity Corporation, and Ariel Corp. and VNG.co argued that natural gas vehicle emissions should return to the 0.15 divisor.[1898]

[1890] Fuel Freedom Foundation, Detailed Comments, NHTSA-2018-0067-12016; National Farmers Union, Detailed Comments, NHTSA-2018-0067-11972.
[1891] Indiana Corn Growers Association, Detailed Comments, NHTSA-2018-0067-12003; Fuel Freedom Foundation, Detailed Comments, NHTSA-2018-0067-12016.
[1892] Fuel Freedom Foundation, Detailed Comments, NHTSA-2018-0067-12016.
[1893] Clean Fuels Development Coalition, Detailed Comments, NHTSA-2018-0067-12031.
[1894] Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1895] Joint submission from Ariel Corp and VNG.co LLC, Detailed Comments, NHTSA-2018-0067-7573; Joint submission from the Coalition for Renewable Natural Gas, NVG America, the American Gas Association, and American Public Gas Association, Detailed Comments, NHTSA-2018-0067-11967.
[1896] See, e.g., joint submission from the Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association, Detailed Comments, NHTSA-2018-0067-11967.
[1897] Joint submission from the Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association, Detailed Comments, NHTSA-2018-0067-11967.
[1898] Ingevity Corporation, Detailed Comments, NHTSA-2018-0067-8666; Joint submission from Ariel Corp. and VNG.co LLC, Detailed Comments, NHTSA-2018-0067-7573.

Ingevity Corporation, Ariel Corp. and VNG.co, the Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association requested that the agencies remove the minimum driving range of natural gas compared to gasoline and "drive to empty" design requirements for dual-fuel natural gas vehicles and allow higher utility factors based on driving range only, so that dual-fuel NGVs are treated similarly to PHEVs. They stated a belief that the design constraints for dual-fuel NGVs ~~a range twice that of electric vehicles~~ holds NGVs to an unfairly higher standard.[1899] As discussed above in Section IX.B, EPA is removing these design constraints for dual-fuel NGVs.

CARB argued that flexibilities for natural gas vehicles and high-octane blend vehicles are not yet warranted.[1900] Similarly, UCS argued that natural gas is a greenhouse gas and benefits from natural gas vehicles are undermined by their costs. UCS further commented that natural gas vehicle technology does not need any incentives since it has already been deployed and in the market.[1901]

In response to comments, NHTSA has determined that EPCA and EISA prescribe the incentive that is used for dedicated liquid and gaseous alternative fuel vehicles, and the CAFE program will continue to use those statutory incentives. For dedicated alternative fuel vehicles, the statute provides a significant incentive that only counts 15 percent of the actual energy used.[1902] For dual fuel vehicles, NHTSA has determined that, for the portion of operation that occurs on an alternative fuel, it is consistent to use the same incentive that is specified by EPCA and EISA for dedicated fuel vehicles. For example, for the hypothetical case of a vehicle that operates 99 percent of the time on an alternative fuel, it would be appropriate for that vehicle to receive nearly the same incentive as a dedicated alternative fuel vehicle that operates 100 percent of the time on alternative fuel. Applying the same 15 percent of energy used incentive for both dedicated and duel fuel vehicles remains appropriate. NHTSA therefore is not adopting any new incentives for any alternative fueled vehicles.

D. Compliance Issues that Affect Both the CO_2 and CAFE Programs

Because the real world CO_2 emissions reduction benefits of certain technologies cannot be measured or fully measured using 2-cycle test procedures, EPA established new compliance flexibilities under its CAA authority, starting in MY 2012, that allow manufacturers credit for emission compliance for installing these technologies. Those flexibilities are designed to recognize improvements in A/C systems with greater efficiency and other "off-cycle" technologies that reduce real world tailpipe CO_2 emissions. More specifically, real world

[1899] Ingevity, Detailed Comments, NHTSA-2018-0067-8666; Joint submission from Ariel Corp. and VNG.co LLC, Detailed Comments, NHTSA-2018-0067-7573; Joint submission from The Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, the American Public Gas Association, Detailed Comments, NHTSA-2018-0067-11967.

[1900] CARB, Detailed Comments, NHTSA-2018-0067-11873.

[1901] UCS, Detailed Comments, NHTSA-2018-0067-12039.

[1902] 32905(a) "... A gallon of a liquid alternative fuel used to operate a dedicated automobile is deemed to contain .15 gallon of fuel." 32905(c) "... One hundred cubic feet of natural gas is deemed to contain .823 gallon equivalent of natural gas. The Secretary of Transportation shall determine the appropriate gallon equivalent of other gaseous fuels. A gallon equivalent of gaseous fuel is deemed to have a fuel content of .15 gallon of fuel."

improvements that cannot be measured or fully measured on 2-cycle tests are determined and used to calculate additional CO_2 credits (in Megagrams (Mg)) for each model type that has the technologies. Because these tailpipe CO_2 improving technologies also impact fuel economy, NHTSA adopted the same flexibilities and incentives beginning in MY 2017. EPA and NHTSA also established incentives for both the CO_2 and CAFE programs that give added compliance credits and fuel consumption improvement values for the production of strong and mild hybrid full-size pickup trucks beginning in MY 2017.[1903] Pursuant to 49 USC 32903, EPA adjusts manufacturers' CAFE performance values using the emissions benefits or incentives provided for these technologies. EPA developed a methodology for manufacturers to increase their passenger car and light truck fuel economy performance in accordance with procedures set forth by EPA in 40 CFR part 600. For the NHTSA CAFE program, the CO_2 reductions (in grams per mile) are converted to fuel consumption improved values (FCIVs, gallons per mile) and then the benefits are summed for all the model types in the manufacturer's fleets. The total FCIVs are used to adjust and increase manufacturers' CAFE (mpg) performance values.

It is important to note that while these flexibilities and incentives have similar value for compliance in the CAFE and CO_2 programs, there are differences in how they are accounted for in each of the programs due to differences in the structure of the programs. The CAFE program accounts for A/C efficiency and off-cycle improvements through EPA measurement procedures that determine *fuel consumption improvement values* (FCIVs). The CAFE A/C efficiency and off-cycle provisions do not involve manufacturer *credits*.[1904] There are no bankable, tradable, or transferrable credits earned by a manufacturer for implementing more efficient A/C systems or installing an off-cycle technology. In fact, the only credits provided for in NHTSA's CAFE program are those earned by overcompliance with a standard.[1905] As discussed above, EPA adjusts CAFE performance values based on the FCIVs generated through the use of these technologies. ~~Specifically, off-cycle technologies and A/C efficiency improvements are used to adjust individual vehicle compliance values based on the fuel consumption improvement values of these technologies. For example, a manufacturer's vehicle *as a whole* may exceed its fuel economy target through the inclusion of A/C efficiency and or off-cycle technologies, and therefore is regarded as a credit-generating vehicle.~~

Commented [A437]: CHANGE AS SHOWN: EPA assumes this text is meant to be about how EPA calculates CAFE, and not about GHGs. But this isn't how either program works; individual vehicles are not held to their target levels, and A/C and OC credits do not impact whether a given vehicle generates credits or not. Footprint targets are used to establish the fleet standards, and model type performance values are used to establish fleet CAFE performance. The fleet performance is then adjusted by applying FCIVs determined from the fleet GHG Megagrams.

Illustrative of this confusion, in the 2016 Alliance/Global petition, the petitioners asked NHTSA to avoid imposing unnecessary restrictions on the use of credits. Alliance/Global referenced language from an EPA report that stated compliance is assessed by measuring the tailpipe emissions of a manufacturer's vehicles, and then reducing vehicle CO_2 compliance values depending on A/C efficiency improvements and off-cycle technologies.[1906] This language is consistent with NHTSA's statement in the MY 2017 and later final rule, which explained how the agencies coordinate and apply off-cycle and A/C adjustments. "There will be separate improvement values for each type of credit, calculated separately for cars and for trucks. These

Commented [A438]: REVISE: EPA notes that this Alliance reference is to a section of the GHG Report where EPA described compliance calculations in a simplified way, for illustrative and plain language purposes for the reader, and this was not meant to reflect the precise way credits are calculated for actual compliance.

[1903] *See* 40 CFR 86.1867-86.1868, 86.1870.
[1904] This is not to be confused with EPA's parallel program, which refers to the consideration of A/C improvements and off-cycle technologies as "credits."
[1905] 49 U.S.C. 32903.
[1906] *See* Alliance/Global Petition at 15.

improvement values are subtracted from the manufacturer's 2-cycle-based fleet fuel consumption value to yield a final new fleet fuel consumption value, which would be inverted to determine a final fleet fuel CAFE value."[1907]

In the NPRM, NHTSA proposed to deny Alliance/Global's request because what the petitioners refer to as "technology credits" are actually FCIVs applied to the fuel economy performance of individual vehicles.[1908] Thus, these adjustments are not actually "credits," per the usage of "credit" in EPCA/EISA and are not subject to the "carry-forward" and "carryback" provisions in 49 U.S.C. 32903. To alleviate confusion, and to ensure consistency in nomenclature, NHTSA proposed to update language in its regulations to reflect that the use of the term "credits" to refer to A/C efficiency and off-cycle technology adjustments should actually be termed fuel consumption improvement values (FCIVs). No further comments were received on this issue in response to the NPRM. For the final rule, NHTSA is finalizing the proposed changes in its regulations to remove the term "credits" and to replace it with the term "adjustments" for the FCIV benefit for A/C and off-cycle technologies in the CAFE program.

Manufacturers seeking to use these flexibilities and incentives start the process each model year by submitting information to EPA and seeking any necessary approvals, as appropriate. The use of certain technologies only requires submitting information to EPA, whereas others require a formal request process for approval. The differences are explained in the following sections. The compliance information manufacturers must submit to EPA describes the technologies, the flexibilities or incentives being used, and the testing approach for deriving benefits. Initial information is required as a part of the EPA certification process, as specified by 40 CFR 86.1843-01 in advance of each model year. For technologies requiring approvals, EPA must confirm the manufacturer's testing approach, receive test results to assess the benefit of the technology, and then where applicable issue a *Federal Register* notice that invites public comment. EPA review and determination usually occurs before the end of the compliance model year, if manufacturers provide information to EPA on a timely basis. To receive the benefit under the CAFE program for technologies that require approvals, manufacturers must concurrently submit to NHTSA the same information that is sent to EPA. EPA consults with NHTSA in reviewing A/C efficiency and off-cycle adjustments to fuel economy performance values that require approval. NHTSA provides EPA its assessment of the suitability of a technology considering: (1) whether the technology has a direct impact upon improving fuel economy performance; (2) whether the technology is related to crash-avoidance technologies, safety critical systems or systems affecting safety-critical functions, or technologies designed for the purpose of reducing the frequency of vehicle crashes; (3) information from any assessments conducted by EPA related to the application, the technology, and/or related technologies; and (4) any other relevant factors.

[1907] 77 FR 62726 (Oct. 15, 2012).

[1908] The agencies also refer to A/C and off-cycle technology improvement values as "credits" sporadically throughout their regulations. NHTSA is amending its regulations to reflect these are adjustments and not actual credits that can be carried forward or back. For a further discussion, see above.

EPA and NHTSA sought comments on several aspects of the shared flexibilities and incentives in the NPRM. Presented in the following sections is a summary of the comments received and the agencies final decisions for the final rule.

1. Incentives for Advanced Technologies in Full-Size Pickup Trucks

In the 2012 rulemaking for MYs 2017 and beyond, EPA and NHTSA finalized incentives for large scale implementation of hybrid electric full size pickup trucks for both the CO_2 and CAFE programs. CO_2 credits and CAFE FCIVs are available for manufacturers that produce full-size pickup trucks with Mild HEV or Strong HEV technology, provided the percentage of production with the technology is greater than specified percentages.[1910] Additionally, CO_2 credits and CAFE FCIVs are available for manufacturers that produce full-size pickups with other technologies that enables full size pickup trucks to exceed performance of their CO_2 or CAFE targets based on footprints by specified amounts.[1911] These performance-based incentive created a technology neutral path to achieve the CO_2 credits and CAFE FCIVs, which would encourage the development and application of new technological approaches.

EPA and NHTSA established limits on the vehicles eligible to qualify for these incentives; a truck must meet minimum criteria for bed size and towing or payload capacity, and meet minimum production thresholds (in terms of a percentage of a manufacturer's full-size pickup truck fleet) in order to qualify for the incentives. Under the existing program, the strong hybrid credit is 20 grams/mile per vehicle, available through MY 2025, if installed on at least 10 percent of the manufacturer's full-size pickup truck fleet in the model year. The program also includes an incentive for mild hybrids of 10 grams/mile per vehicle during MYs 2017–2021. To be eligible the manufacturer would have to show that the mild hybrid technology is utilized in a specified portion of its truck fleet beginning with at least 20 percent of a company's full-size pickup production in MY 2017 and ramping up to at least 80 percent in MY 2021.[1911]

At present, no manufacturer has qualified to use the full-size pickup truck incentives. One vehicle manufacturer introduced a mild hybrid pickup truck for MY 2019 but ~~failed to~~did not meet the minimum production threshold. Others have announced potential collaborations, or have already started production on future hybrid or electric models.[1912] ~~However, the agencies~~

Commented [A439]: CHANGE AS SHOWN: We suggest deleting this sentence as it appears to be an author's opinion. If there is some supporting technical basis for the statement it should be cited.

[1910] 77 FR 62651 (Oct. 15, 2012).
[1911] *Id.*
[1911] 77 FR 62651-2 (Oct. 15, 2012).
[1912] Chrysler released the 2019 Dodge Ram 1500 "eTorque" (see https://www.fueleconomy.gov/feg/Find.do?action=sbs&id=40736&id=40737&id=40394&id=40397) which qualifies as a mild hybrid pickup truck by replacing the traditional alternator on the engine with a 48-volt Li-on battery-powered, belt-driven motor generator that improves performance, efficiency, payload, towing capabilities and drivability. The production volume of these vehicles did not qualify for the full-size pickup truck electric/hybrid incentive for MY 2019. Other vehicle models are currently in research or in development for future years but it is uncertain ~~whether~~ whether they will reach the required sales volumes to qualify for incentives. For example, *the hybrid and battery-electric versions of the F-150 pickup*, see https://www.trucks.com/2019/09/18/ford-truck-engineer-explains-electric-f-150-pickup-plans (September 18, 2019), or the new electric pickup truck manufactured by Rivian, https://www.trucks.com/2019/04/24/ford-plans-new-electric-truck-rivian-invests-500-million/ (April 24,

~~continue to be aware that there may not ever be sufficient consumer interest for these full-size pickup truck technologies to reach significant or qualifying volumes, as consumers may believe that they are less durable or provide reduced utility.~~

Prior to the NPRM, the agencies received input from automakers that these incentives should be extended and available to all light-duty trucks (e.g., cross-over vehicles, minivans, sport utility vehicles, and smaller-sized pickups) and not only full-size pickup trucks.[1913] Automakers also recommended that the program's eligibility production thresholds should be removed because they discourage the application of technology since manufacturers cannot be confident of achieving the thresholds. Some stakeholders have also suggested an additional incentive for strong and mild hybrid passenger cars. In the proposal, the agencies sought comment on whether these incentives should be expanded along the lines suggested by stakeholders, on the basis that perhaps these incentives could lead to additional product offerings of strong hybrids, and technologies that offer similar emissions reductions, which could enable manufacturers to achieve additional long-term CO_2 emissions reductions. Additionally, the agencies sought comment on whether to extend either the incentive for hybrid full-size pickup trucks or the performance-based incentive past the dates that EPA specified in the 2012 final rule for MY 2017 and later. ~~The agencies also sought comment on eliminating all incentive programs, as discussed above.~~

Commented [A440]: CHANGE AS SHOWN: We did not see in the NPRM where NHTSA sought comment on eliminating "all" incentive programs. E.g., we see NHTSA's request for comment on extending the incentives at 43454 but cannot find a request for comment on eliminating the incentives. For example, NPRM X.D. only discusses eliminating A/C efficiency and off-cycle credits.

The agencies received a variety of comments on the full-size pickup truck incentives. Comments were received from General Motors, Volkswagen, Honda, BorgWarner, Fiat Chrysler, Toyota, DENSO International, Ford, CARB, Global Automakers, UCS, Electric Drive Transportation Association, the Auto Alliance, Ariel Corp. and VNG.co, ACEEE, the Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association.

The Auto Alliance, Toyota, General Motors, BorgWarner, Global Automakers, and Volkswagen advocated to expand the full-size pickup truck hybrid incentives to all hybrid vehicles.[1914] They argued that prices for all hybrid-drive technologies are projected to remain high and consumer demand for these vehicles is still slow to increase.[1915] They asserted that expanding the full-size pickup truck hybrid incentive to all hybrid vehicles will help encourage investments in hybrid technology and continue to help manufacturers address their compliance challenges.[1916] Similarly, these commenters reported that the current market, fueled by consumer demand for SUVs and lower than expected gas prices, is not conducive to consumer

2019); or the Tesla all electric pickup truck (https://www.cnn.com/2019/11/08/success/tesla-pickup-reveal/index.html) (November 8, 2019).

[1913] 83 FR 43461 (Aug. 24, 2018).

[1914] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Toyota, Detailed Comments, NHTSA-2018-0067-12150; General Motors, Detailed Comments, NHTSA-2018-0067-11858; BorgWarner, Detailed Comments, NHTSA-2018-0067-11895; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.

[1915] See, e.g., Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

[1916] See, e.g., General Motors, Detailed Comments, NHTSA-2018-0067-11858.

acceptance of or demand for electric vehicles.[1917] For these reasons, they stated their belief that it is important to support adjustments and expansion of the current incentives to promote hybrid technologies.

The Auto Alliance, DENSO International, Global Automakers, Fiat Chrysler, and Honda also argued for alternative pathways for the agencies to consider allowing the full-size pickup truck hybrid incentives to be expanded to the light-duty truck segment, but not to all passenger vehicles. They argued that hybrid technology has been slow to be applied in the light-duty truck segment, but has been broadly applied to passenger cars.[1918]

Toyota, Global Automakers, and the Auto Alliance suggested the incentives for light-duty trucks should amount to 20 grams/mile.[1919] Global Automakers added that in addition to expanding full-size pickup truck hybrid incentives to light trucks, the agency should consider a smaller incentive for hybrid electric passenger vehicles as well.[1920] The Auto Alliance and Toyota suggested a 10 grams/mile credit for passenger cars.[1921] Volkswagen further requested the hybrid pickup credit to be expanded to all hybrid cars and trucks.[1922]

Toyota, the Auto Alliance, Electric Drive Transportation Association, Ford, DENSO International, Global Automakers, Fiat Chrysler, and BorgWarner commented that having minimum production percentages for hybrid pickup trucks discourages manufacturers from investiug in hybrid technologies. They requested that the agencies consider eliminating the percentage of production requirement and provide incentives in proportion to the value of the technology.[1923] Ford stated that the minimum production percentages unfairly penalize larger manufacturers who must produce more pickup trucks to claim the incentives than a smaller volume manufacturer.[1924]

Ariel Corp. and VNG.co, the Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association commented the pickup

[1917] See, e.g., Toyota, Detailed Comments, NHTSA-2018-0067-12150.
[1918] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; DENSO, Detailed Comments, NHTSA-2018-0067-11880; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Honda, Detailed Comments, NHTSA-2018-0067-11818.
[1919] Toyota, Detailed Comments, NHTSA-2018-0067-12150; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1920] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.
[1921] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Toyota, Detailed Comments, NHTSA-2018-0067-12150.
[1922] Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1923] Toyota, Detailed Comments, NHTSA-2018-0067-12150; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Electric Drive Transportation Association, Detailed Comments, NHTSA-2018-0067-1201; Ford, Detailed Comments, NHTSA-2018-0067-11928; DENSO, Detailed Comments, NHTSA-2018-0067-11880; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; BorgWarner, Detailed Comments, NHTSA-2018-0067-11895.
[1924] Ford, Detailed Comments, NHTSA-2018-0067-11928.

truck incentives should be expanded to include natural gas vehicles.[1925] They suggested a "Natural Gas Pickup" incentive like the hybrid-electric and performance-based pickup credits, but no minimum production requirement.[1926]

ACEEE and UCS commented that hybrid technology has been around for quite a while and has been applied in every vehicle class. They discouraged the agencies from applying more incentives to these vehicles.[1927] Specifically, UCS stated that incentives for electric vehicles are mostly driven by state regulation, and EPA and NHTSA policies are rewarding manufacturers for meeting standards they were already required to meet.[1928] UCS commented that hybrids are not innovators or game-changing vehicles—they are simply one of many strategies by which manufacturers can reduce emissions and should not receive special treatment.[1929]

CARB commented that incentives for full-size hybrid pickup trucks should remain limited in their scope and that increasing or expanding those incentives can erode emissions benefits.[1930] CARB further commented that hybrid electric vehicles (HEVs) are widely available at varying levels of power and performance across vehicle sizes, and CARB does not believe HEVs deserve special treatment in the CO_2 vehicle regulations.

After carefully considering the comments received, EPA and NHTSA are not adopting any new or expanded incentives for hybrid vehicles or full-size pickup trucks. The final revised standards are projected to be achievable without such added incentives and any new incentives would result in the loss of emissions benefits to the extent that they were used by manufacturers. ~~The agencies believe any new or expanded incentives would likely not result in any further emissions benefits or fuel economy improvements since an increase in sales volume would not be expected.~~ The agencies agree with CARB and ACEEE, and UCS that hybrids are a well-established technology that has already been applied to a wide range of vehicles and, as such, no further incentives are warranted at this time. ~~Further, the agencies believe that incentivizing manufacturers to implement specific technologies is inappropriate, as manufacturer fuel economy performance should represent actual fuel consumption.~~ The agencies believe any new or expanded incentives for hybrids would likely not result in any further emissions benefits or fuel economy improvements beyond those measured during testing. Manufacturers did not provide sufficient evidence to support their position in a manner that leads the agencies to conclude otherwise.

Commented [A441]: CHANGE AS SHOWN: EPA believes it is important to retain this text as suggested in our earlier draft.

[1925] Joint submission from Ariel Corp. and VNG.co, Detailed Comments, NHTSA-2018-0067-7573; Joint submission from The Coalition for Renewable Natural Gas, NGVAmerica, the American Gas Association, and the American Public Gas Association, Detailed Comments, NHTSA-2018-0067-11967.
[1926] See, e.g., Joint submission from Ariel Corp. and VNG.co, Detailed Comments, NHTSA-2018-0067-7573.
[1927] ACEEE, Detailed Comments, NHTSA-2018-0067-12122-29; UCS, Detailed Comments, NHTSA-2018-0067-12039.
[1928] UCS, Detailed Comments, NHTSA-2018-0067-12039.
[1929] UCS, Detailed Comments, NHTSA-2018-0067-12039.
[1930] CARB, Detailed Comments, NHTSA-2018-0067-11873.

2. Flexibilities for Air Conditioning Efficiency

A/C systems are virtually standard automotive accessories, and more than 95 percent of new cars and light trucks sold in the U.S. are equipped with mobile A/C systems. A/C system usage places a load on an engine, which results in additional tailpipe CO_2 emissions and fuel consumption; the high penetration rate of A/C systems throughout the light-duty vehicle fleet means that efficient systems can significantly impact the total energy consumed and CO_2 emissions. A/C systems also have non-CO_2 emissions associated with refrigerant leakage.[1931] Manufacturers can improve the efficiency of A/C systems though redesigned and refined A/C system components and controls.[1932] That said, such improvements are not measurable or recognized using 2-cycle test procedures, since A/C is turned off during 2-cycle testing. Any A/C system efficiency improvements that reduce load on the engine and improve fuel economy is therefore not measurable on those tests.

The CO_2 and CAFE programs include flexibilities to account for the real world CO_2 emissions and fuel economy improvements associated with improved A/C systems and to include the improvements for compliance.[1933] The total of A/C efficiency credits is calculated by summing the individual credit values for each efficiency improving technology used on a vehicle, as specified in the A/C credit menu. The total A/C efficiency credit sum for each vehicle is capped at 5.0 grams/mile for cars and 7.2 grams/mile for trucks. Additionally, the off-cycle credit program contains credit earning opportunities for technologies that reduce the thermal loads on a vehicle from environmental conditions (solar loads or parked interior air temperature).[1934] These technologies are listed on a thermal control menu that provides a predefined improvement value for each technology. If a vehicle has more than one thermal load improvement technology, the improvement values are added together, but subject to a cap of 3.0 grams/mile for cars and 4.3 grams/mile for trucks.

EPA requested comment on the A/C caps and on whether A/C efficiency technologies and off-cycle thermal control technologies should be combined under a single cap, since the technologies directly interact with each other. That is, improved thermal control results in reduced A/C loads for the more efficient A/C technologies. If the thermal credits were removed from the off-cycle menu, they would no longer be counted against the 10 grams/mile menu cap

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[1931] See Section [xxx] for further details. Notably, manufacturers cannot claim CAFE-related benefits for reducing A/C leakage or switching to an A/C refrigerant with a lower global warming potential. While these improvements reduce emissions consistent with the purpose of the CAA, they generally do not impact fuel economy and, thus, are not relevant to the CAFE program.

[1932] The approach for recognizing potential A/C efficiency gains is to utilize, in most cases, existing vehicle technology/componentry, but with improved energy efficiency of the technology designs and operation. For example, most of the additional A/C-related load on an engine is because of the compressor, which pumps the refrigerant around the system loop. The less the compressor operates, the less load the compressor places on the engine resulting in less fuel consumption and CO_2 emissions. Thus, optimizing compressor operation with cabin demand using more sophisticated sensors, controls, and control strategies is one path to improving the efficiency of the A/C system. For further discussion of A/C efficiency technologies, see Section II.D of the NPRM and Chapter 6 of the accompanying PRIA.

[1933] *See* 40 CFR 86.1868-12.

[1934] *See* 40 CFR 86.1869-12(b).

discussed above, representing a way to provide more room under the menu cap for other off-cycle technologies. Specifically, EPA sought comment on replacing the current off-cycle thermal efficiency capped value of 10 grams/mile, with separate caps of 8 grams/mile for cars and 11.5 grams/mile for trucks.

Comments concerning the A/C caps were received from the Auto Alliance, DENSO, Fiat Chrysler, and Volkswagen. DENSO commented that A/C efficiency credits earned through the off-cycle petition process should not count toward the A/C credit cap. If A/C credits granted through the off-cycle petition process are no longer counted toward the A/C credit cap, it stated that manufacturers would be significantly incentivized to develop new and innovative technologies.[1935] Fiat Chrysler requested that certain A/C credits for electrical technologies be transferred to the off-cycle credit list.[1936] Volkswagen further supported the removal of the thermal control technology credit caps and suggested that implementing caps at the fleet average level, rather than per-vehicle, could be less constraining.[1937] DENSO pointed to an NREL study which found that A/C improvements were greater than previously thought possible. Therefore, it requested the agencies consider increasing the A/C credit cap.[1938]

Similarly, the Auto Alliance and Fiat Chrysler suggested raising the cap on A/C efficiency and thermal control technology by 64 percent and combine them under a single cap.[1939] Additionally, they proposed increasing A/C efficiency and thermal control technology credits by up to 64 percent.[1940] They also proposed that the agencies create new regulatory provisions to handle additional new A/C and thermal technologies.[1941]

As with increasing the credit caps, manufacturers and suppliers were generally supportive of higher credit caps, or no caps at all, for this combined technology group. However, EPA has decided not to adopt any changes to the caps, including combining the A/C efficiency and thermal controls menu, due to the uncertainty regarding the menu credit values. Additional uncertainty exists for these technology groups because there are likely synergistic effects between A/C efficiency and thermal technologies that would need to be further considered in determining appropriate credit levels if the two groups of technologies are combined under a single cap. Data is not currently available to consider these effects. Therefore, the agencies are not making any changes to the flexibilities for A/C efficiency improvements in the CO_2 or CAFE program, but may perform research to understand better the relationship between A/C efficiency and thermal technologies for consideration ~~that may lead to a different approach~~ in future rulemakings.

[1935] DENSO, Detailed Comments, NHTSA-2018-0067-11880.
[1936] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1937] Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1938] DENSO, Detailed Comments, NHTSA-2018-0067-11880.
[1939] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1940] See, e.g., Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.
[1941] See, e.g., Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

3. Flexibilities for Off-Cycle Technologies

"Off-cycle" technologies are those that reduce vehicle fuel consumption and CO_2 emissions in the real world, but for which the fuel consumption reduction benefits cannot be measured or cannot be fully measured under the 2-cycle test procedures (city, highway or correspondingly FTP, HFET) used to determine compliance with the fleet average standards. The CAFE city and highway test cycles, collectively referred to as the 2-cycle laboratory compliance tests (or 2-cycle tests), were developed in the early 1970s. The city test simulates city driving in the Los Angeles area at that time. The highway test simulates driving on secondary roads (not expressways). The cycles are effective in measuring improvements in most fuel economy improving technologies; however, they are unable to measure or underrepresent certain fuel economy improving technologies because of limitations in the test cycles. For example, off-cycle technologies that improve emissions and fuel economy at idle (such as "stop start" systems) and those technologies that improve fuel economy to the greatest extent at expressway speeds (such as active grille shutters which improve aerodynamics) receive less than their real-world benefits in the 2-cycle compliance tests.

Starting with MY 2008, EPA began employing a "five-cycle" test methodology to measure fuel economy for the purpose of improving new car window stickers (labels) and giving consumers better information about the fuel economy they could expect under real-world driving conditions.[1942] However, for CO_2 and CAFE compliance, EPA continues to use the established "two-cycle" test methodology.[1943] As learned through development of the "five-cycle" methodology and prior rulemakings, there are technologies that provide real-world CO_2 emissions and fuel consumption improvements, but those improvements are not fully reflected on the "two-cycle" test. EPA established the off-cycle credit program to provide an appropriate level of CO_2 credit for technologies that achieve CO_2 reductions, but are normally not chosen as a CO_2 control strategy because their CO_2 benefits are not measured on the specified 2-cycle test.

Currently, EPA has three compliance pathways~~, and intends substantially to streamline the processes for using off-cycle compliance flexibilities~~. The first approach allows manufacturers to gain credits without having to prove the benefits of the technologies on a case-by-case basis. A predetermined list or "menu" of credit values for specific off-cycle technologies exists and became effective starting in MY 2014.[1944] This pathway allows manufacturers to use credit values established by EPA for a wide range of off-cycle technologies, with minimal or no data submittal or testing requirements.[1945] Specifically, EPA

[1942] https://www.epa.gov/vehicle-and-fuel-emissions-testing/dynamometer-drive-schedules.
[1943] The city and highway test cycles, commonly referred to together as the 2-cycle tests are laboratory compliance tests required by law for CAFE and are also used for determining compliance with the CO_2 standards.
[1944] *See* 40 CFR 86.1869-12(b).
[1945] The Technical Support Document (TSD) for the 2012 final rule for MYs 2017 and beyond provides technology examples and guidance with respect to the potential pathways to achieve the desired physical impact of a specific off-cycle technology from the menu and provides the foundation for the analysis justifying the credits provided by the menu. The expectation is that manufacturers will use the information in the TSD to design and implement off-cycle technologies that meet or exceed those expectations in order to achieve the real-world benefits of off-cycle technologies from the menu.

established a menu with a number of technologies that have real-world CO_2 and fuel consumption benefits not measured, or not fully measured, by the two-cycle test procedures, and those benefits were reasonably quantified by the agencies at that time. For each of the pre-approved technologies on the menu, EPA established a quantified default value that is available without additional testing. Manufacturers must demonstrate that they were in fact using the menu technology, but not required to conduct testing to quantify the technology's effects, unless they wish to receive a credit larger than the default value. The default values for these off-cycle credits were largely determined from research, analysis, and simulations, rather than from full vehicle testing, which would have been both cost and time prohibitive. EPA generally used conservative predefined estimates to avoid any potential credit windfall.[1946]

For off-cycle technologies not on the pre-defined technology list, or obtained through petitioning, EPA created a second pathway which allows manufacturers to use 5-cycle testing to demonstrate and justify off-cycle CO_2 credits.[1947] EPA established this alternative for a manufacturer to demonstrate the benefits of the technology using 5-cycle testing. The additional emissions tests allow emission benefits to be demonstrated over some elements of real-world driving not captured by the CO_2 compliance tests, including high speeds, rapid accelerations, and cold temperatures. Under this pathway, manufacturers submit test data to EPA, and EPA determines whether there is sufficient technical basis to approve the off-cycle credits. No public comment~~s~~ period is ~~are~~ required for manufacturers seeking credits using the EPA ~~picklist~~ menu or using 5-cycle testing.

Commented [A442]: CHANGE AS SHOWN: EPA and most commenters refer to the pre-approved credits as a "menu" rather than "picklist."

The third pathway ~~EPA designed for gaining off-cycle credits allows manufacturers that believe their specific off-cycle technology, either on the EPA picklist menu or not, achieves larger improvements to apply for greater credits and fuel consumption improvement values with supporting data using a case-by-case demonstration approach. This third pathway~~ allows manufacturers to seek EPA approval, through a notice and comment process, to use *an alternative methodology other than the menu or 5-cycle methodology* for determining the off-cycle technology CO_2 credits.[1948] Manufacturers must provide supporting data on a case-by-case basis demonstrating the benefits of the off-cycle technology on their vehicle models. Manufacturers may also use the third pathway to apply for credits and FCIVs for menu technologies where the manufacturer is able to demonstrate credits and FCIVs greater than those provided by the menu.

Due to the uncertainties associated with combining ~~picklist~~ menu technologies and the fact that some uncertainty is introduced because off-cycle credits are provided based on a general

[1946] While many of the assumptions made for the analysis were conservative, others were "central." For example, in some cases, an average vehicle was selected on which the analysis was conducted. In that case, a smaller vehicle may presumably deserve fewer credits whereas a larger vehicle may deserve more. Where the estimates are central, it would be inappropriate for the agencies to grant greater credit for larger vehicles, since this value is already balanced by smaller vehicles in the fleet. The agencies take these matters into consideration when applications are submitted for credits beyond those provided~~to modify credits~~ on the menu.

[1947] *See* 40 CFR 86.1869-12(c). EPA proposed a correction for the 5-cycle pathway in a separate technical amendments rulemaking. *See* 83 FR 49344 (Oct. 1, 2019). EPA is not approving credits based on the 5-cycle pathway pending the finalization of the technical amendments rule.

[1948] *See* 40 CFR 86.1869-12(d).

assessment of off-cycle performance, as opposed to testing on the individual vehicle models. EPA established caps that limit the amount of credits a manufacturer may generate using the EPA ~~picklist~~ menu. Off-cycle technology is capped at 10 grams/mile per year on a combined car and truck fleet-wide average basis. ~~EPA also established minimum penetration rates for several of the listed technologies, as a condition for generating credit from the list, as a further way to encourage their adoption.~~ No caps were established for technologies gaining credits through the petitioning or 5-cycle approval methodologies.

Commented [A443]: CHANGE AS SHOWN: There are no production thresholds in the off-cycle program.

a) Consideration of Eliminating A/C and Off-Cycle Adjustments in the CO_2 and CAFE Programs

The agencies sought comments in the NPRM on whether to remove the A/C and off-cycle flexibilities from the CAFE program and adjust the stringency levels accordingly based upon concern that the flexibilities might distort the market. Several commenters provided responses concerning the feasibility of removing any of these flexibilities. Commenters included the Auto Alliance, the National Automobile Dealers Association, Global Automakers, the Alliance for Vehicle Efficiency, ACEEE, BorgWarner, Fiat Chrysler, General Motors, International Council on Clean Transportation, Toyota, and UCS. Other comments were received requesting that the agencies look into expanding the flexibilities by including more technologies.

There was widespread support from commenters for retaining these flexibilities for A/C and off-cycle technologies in the CO_2 and CAFE programs. Commenters preferred that the agencies continue to include the flexibilities, believing them to enable real world fuel economy improvements and compliance with CO_2 and CAFE standards with a more cost effective combination of technologies. The agencies agree that these programs achieve real world fuel economy improvements and that keeping the flexibilities may enable more cost effective technology combinations to achieve those real world fuel economy improvements. For MY 2017, manufacturers introduced a wide variety of low-cost technologies through the A/C and off-cycle flexibilities that increased the overall industry's CAFE performance by 1.1 mpg. The agencies also acknowledge that the continued use of these flexibilities under the EPA program since 2012 warrants consideration due to automakers' and suppliers' significant investments in developing the technologies, which could result in stranded capital should the agencies discontinue them and manufacturers choose to remove the technologies. For these reasons, the agencies have decided to continue allowing manufacturers to use the existing flexibilities for A/C efficiency and off-cycle technologies for future model years.

b) Final Decisions in Response to Manufacturers' and Suppliers' Requests

Automakers, trade associations, and auto suppliers recommended several changes to the current off-cycle credit program.[1949] Prior to the NPRM, automakers and suppliers suggested changes to the off-cycle program, including:

[1949] *See generally* Alliance/Global Petition.

- Streamlining the program in ways that would give auto manufacturers more certainty and make it easier for manufacturers to earn credits;
- Expanding the current pre-defined off-cycle credit menu to include additional technologies and increasing credit levels where appropriate;
- Eliminating or increasing the credit cap on the pre-defined list of off-cycle technologies and revising the thermal technology credit cap; and
- Creating a role for suppliers directly to seek approval of their technologies.

EPA requested comments on several aspects of the off-cycle credits program and, as discussed below, both EPA and NHTSA are adopting some modest changes, primarily to help streamline and clarify their programs, and to ease the implementation burden for manufacturers and the government. The agencies are not adopting a significant expansion of the programs in this rule, as also discussed below. EPA and NHTSA are taking this relatively conservative approach for their off-cycle programs due to the uncertainty that remains in estimating off-cycle benefits of technologies and the need to remain cautious to help ensure that emissions and fuel economy benefits expected through the off-cycle flexibility are realized in the real-world. EPA notes that the standards finalized in today's rule are projected to be achievable without an expanded off-cycle credits program and therefore EPA does not believe expanding the program is necessary for compliance.

Commented [A444]: CHANGE AS SHOWN: EPA believes it is important to retain this text that was in our draft Enhanced Flexibilities preamble.

(1) Program Streamlining

EPA requested comments on changes to the off-cycle process that would streamline the program. Currently, under the third pathway, manufacturers submit an application that includes the methodology they used to determine the off-cycle credit value and data, which then undergoes a public notice and comment process prior to an EPA decision regarding the application. Each manufacturer separately submits an application to EPA that must undergo a public notice and comment process even if the manufacturer uses a methodology previously approved by EPA for another manufacturer. For example, under the current program, multiple manufacturers have separately submitted applications for high-efficiency alternators and advanced A/C compressors using similar methodologies and producing similar levels of credits. If manufacturers also seek fuel economy improvement values for the CAFE program, they are also required to send the submissions to NHTSA, as EPA consults with NHTSA in its determinations for the CAFE program. NHTSA's involvement is discussed in more detail in Section VIII.D.3.b).

EPA requested comment on revising the regulations to allow all auto manufacturers to make use of a methodology once it has been approved by EPA under the public process, without subsequent applications from other manufacturers having to undergo the same process. This would reduce redundancy in the current program. ~~This would reduce redundancy in the current program.~~ Manufacturers would need to provide EPA with at least the same level of data and detail for the technology and methodology as the manufacturer that went through the initial public notice and comment process.

EPA received supportive comments for streamlining the approval process from auto manufacturers and suppliers. The Auto Alliance commented that it supports all actions that would shorten the time it takes EPA to evaluate and reach decisions on applications through the

off-cycle alternative methodology pathway, and that manufacturers should be allowed to use common data from applications that have already been approved.[1950] Such common data would include ambient conditions, general consumer behavior data, and general operating and performance data for the same off-cycle technologies. Global Automakers also commented that EPA should streamline efforts to avoid reduplication of applications in situations where multiple automakers have submitted petitions for the same technology and recommended blanket approval for applications using the same specific technologies and calculation and measurement procedures.[1951] General Motors commented that when a credit for a new technology is approved for one manufacturer, the EPA decision document announcing that approval can serve as a guidance document that assigns a credit value or calculation methodology for the technology for all manufacturers without requiring duplicative testing.[1952] MEMA commented that it would be sufficient to uphold the integrity of the off-cycle program to require the next vehicle manufacturer's application to provide at least the same level of data and details as the original vehicle manufacturer application and to validate the level of credit the next vehicle manufacturer is applying for based on how the technology is applied in its fleet.[1953]

ACEEE commented that any streamlining of the process by which automakers petition for off-cycle credits must maintain the requirement that a thorough methodology show real-world benefits and ensure adequate opportunity for public review.[1954] International Council on Clean Transportation (ICCT), while not commenting on this specific request for comment, commented that the program should remain unchanged until potential changes can be further analyzed.[1955]

After considering the comments, consistent with its request for comments~~proposal~~, EPA is streamlining the approval process as follows: once a methodology for a specific off-cycle technology has gone through the public notice and comment process and is approved for one manufacturer, other manufacturers may follow the same methodology to collect data on which to base their off-cycle credits. Once a methodology is approved, other manufacturers may submit applications citing the approved methodology, but those manufacturers must provide their own necessary test data, modeling, and calculations of credit value specific to their vehicles, and any other vehicle-specific details pursuant to that methodology, to assess an appropriate credit value. This is similar to what occurred, for example, with the advanced A/C compressor, where one manufacturer applied for credits with data collected through bench testing and vehicle testing and subsequent manufacturers applied for credits following the same methodology, but by submitting test data specific to their vehicle models. However, those subsequent applications previously required a public notice and comment process. For future applications, as long as the testing is conducted using the previously-approved methodology, EPA will evaluate the credit

Commented [A445]: CHANGE AS SHOWN: The NPRM includes a request for comment, not a proposal.

[1950] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1951] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.
[1952] General Motors, Detailed Comments, NHTSA-2018-0067-11858-21.
[1953] MEMA, EPA-HQ-OAR-2018-0283-5692. See https://www.mema.org/sites/default/files/resource/MEMA%20CAFE%20and%20GHG%20Vehicle%20Comments%20FINAL%20with%20Appendices%20Oct%2026%202018.pdf.
[1954] ACEEE, Detailed Comments, NHTSA-2018-0067-12122.
[1955] International Council on Clean Transportation, Detailed Comments, NHTSA-2018-0067-11741.

application and issue a decision with no additional notice and comment, since the first application that established the methodology was subject to notice and comment.

EPA is not providing blanket approval for a specific credit value, nor amending the requirement that manufacturers collect necessary data or perform modeling or other analyses on their specific vehicle models as the basis for the credit. However, once a methodology has been fully vetted and approved through the public process, EPA believes additional public review of the identical methodology is unnecessarily duplicative. In EPA's experience thus far (for example with high-efficiency alternators and advanced A/C compressors for which EPA has received applications from several manufacturers based on the same methodology), additional public review has yielded no additional substantive public comments. EPA believes this change in the program will help reduce the time necessary for review of applications. EPA will maintain the option to seek additional public comment in cases where the agency believes a new application deviates from a previously approved methodology or raises new issues on which the agency believes it is prudent to seek comment.

EPA also requested comment on revising the regulations to allow EPA to, in effect, add technologies to the pre-approved credit menu without going through a subsequent rulemaking. For example, if one or more manufacturers submit applications with sufficient supporting data for the same or similar technology, the data from that application(s) could potentially be used by EPA as the basis for adding technologies to the menu. EPA requested comment on revising the regulations to allow EPA to establish through a decision document a credit value, or scalable value as appropriate, and technology definitions or other criteria to be used for determining whether a technology qualifies for the new menu credit. As envisioned in the NPRM, this streamlined process of adding a technology to the menu would involve an opportunity for public review but not a formal rulemaking to revise the regulations, allowing EPA to add technologies to the menu in a timely manner, where EPA believes that sufficient data exist to estimate an appropriate credit level for that technology across the fleet.

EPA received supportive comments regarding this ~~proposal~~ request for comments from auto manufacturers and suppliers who believe that the change would help streamline the program. EPA also received comments from environmental NGOs suggesting that the program should not be changed at this time. After consideration of these comments, the agencies are not revising the regulations to allow technologies to be added to the menu without a rulemaking because EPA believes that menu-based off-cycle credits should be based on a robust demonstration of the technology, consistent with the regulations. The agencies will retain the option to add technologies to the menu through a rulemaking, similar to the approach being taken for high-efficiency alternators and advanced A/C compressors as discussed below, where sufficient data has been collected from multiple manufacturers and vehicle models on which to base a menu credit. The menu credits are meant to be conservative. The agencies are concerned that basing a menu credit on data from only one or a few manufacturers does not guarantee a robust and accurate credit level representing vehicles across the fleet. At this time, the agencies continue to believe a rulemaking process with full opportunity for public comment remains the best approach for adding technologies to the menu. A rulemaking ensures that all stakeholders including automakers have an opportunity to provide data to support an appropriate and conservative credit level for the fleet. This approach also provides an incentive for

Commented [A446]: CHANGE AS SHOWN: EPA did not propose these changes, only requested comment.

manufacturers to, in the meantime, continue to perform testing and provide actual data that could eventually be used to inform a rulemaking process to add a technology to the menu. The agencies want to preserve that element of the program to maintain the integrity of off-cycle credits representing real-world reductions.

(2) A/C and Off-Cycle Application Process

The agencies received several comments, in addition to those received in the petitions from the Auto Alliance and Global Automakers, discussed below, on the application process for approving additional A/C and off-cycle credits. Commenters included the Global Automakers, the Auto Alliance, Volkswagen, Edison Electric Institute, Ford, Fiat Chrysler, NCAT, Toyota, General Motors, and DENSO International.

Fiat Chrysler, Ford, Volkswagen, DENSO International, Global Automakers, and the Auto Alliance requested that the agencies respond more quickly to applications for A/C and off-cycle technologies.[1956] They prefer that petitions be addressed before the close of a model year so manufacturers can have a better idea of what credits they will earn.

The agencies agree that responding to petitions before the end of a model year is beneficial to manufacturers and the government. Manufacturers would have a better idea of the approved credits, and the government could carry-out its compliance processes more efficiently. EPA structured the A/C and off-cycle programs to make it possible to complete the processes by the end of the model year so manufacturers could submit their final reports within the required deadline, 90 days after the calendar year. However, delays currently exist due to the timing needed to review and approve technologies for the first time and issue *Federal Register* notices seeking public comments, where applicable. The agencies anticipate these problems will resolve themselves as the off-cycle program reaches maturity and EPA initiates the new streamlining approaches adopted in this final rule, discussed in the previous section.

The agencies are also aware that delays exist because manufacturers frequently submit late applications, new applications, and ask for retroactive credits or FCIVs for off-cycle technologies equipped on previously-manufactured vehicles after the model year has ended. As required under both the CO_2 and CAFE programs, manufacturers are to submit applications for off-cycle credits and FCIVs *before* the beginning of each compliance model year, to enable the agencies to make better informed final decisions before the model year ends. ~~Consequently, NHTSA and EPA are considering incorporating deadlines for manufacturers and other actions the government may take to expedite the processes.~~

Commented [A447]: CHANGE AS SHOWN: EPA is not considering such reg changes and even if we were, we see no reason to explicate what the agency may be thinking about doing in the future unless its needed to respond to comments, which this does not seem to be.

[1956] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943-50; Ford, Detailed Comments, NHTSA-2018-0067-11928-15; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583-13; DENSO, Detailed Comments, NHTSA-2018-0067-11880-5; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032-50; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073-120.

~~In the meantime, t~~To expedite the process of approvals, the agencies will enforce existing EPA and NHTSA regulations requiring manufacturers to notify and report information on the technologies before the beginning of the model year. Presently, manufacturers must notify EPA in their pre-model year reports, and in their applications for certification, of their intention to generate any A/C and off-cycle credits before the model year, regardless of the methodology for generating credits.[1957] Manufacturers choosing to generate credits using the alternative EPA-approval methodology are required to submit a detailed analytical plan to EPA *prior to a model year* in which a manufacturer intends to seek these credits. The manufacturer may seek EPA input on the proposed methodology prior to conducting testing or analytical work, and EPA will provide input on the manufacturer's analytical plan. The alternative demonstration program must be approved in advance by the Administrator. NHTSA has similar provisions for its projections reports in which detailed information on the technologies must be included in those submissions during the month of December before the model year.[1958] NHTSA's provisions also require manufacturers to submit information to NHTSA at the same time as to EPA. Consequently, the eligibility of a manufacturer to gain off-cycle CO_2 credits or CAFE adjustments for a given compliance model year requires appropriate submissions to the agencies. The agencies intend to enforce these provisions starting with the 2020 compliance model year. Manufacturers may resubmit MY 2020 information until May 1, 2020. After that time, ~~T~~the agencies will deny any manufacturers' late submissions requesting retroactive credits ~~after that time, including those requesting retroactive credits~~ for previous compliance model years. However, manufacturers who properly submit information ahead of time will be allowed to make corrections to resolve inadvertent errors during or after the model year. The agencies believe that enforcing the existing submission requirements will be the most efficient approach to expedite approvals until new regulatory deadlines or additional requirements can be adopted.

Fiat Chrysler, Volkswagen, Global Automakers, and the Auto Alliance further suggested the EPA issue a *Federal Register* notice for submitted off-cycle applications within 30 days and issue a final decision within 90 days.[1959]

As mentioned, EPA is addressing the issues raised by commenters by streamlining its required regulatory processes to eliminate the need to submit multiple *Federal Register* notices concerning requests from different manufacturers for the same technology. Under this streamlined process, after a technology is approved for the initial manufacturer(s), EPA will approve any subsequent manufacturer requests for the same technology upon receipt of data submissions validating the benefit specific to their model types.

General Motors, Toyota, NCAT, Fiat Chrysler, Ford, Volkswagen, DENSO, Edison Electric Institute, Global Automakers, and the Auto Alliance further suggested that technologies approved for multiple manufacturers, to the extent additional automakers will have the same requests, be added to the ~~"picklist"~~menu to encourage additional implementation of the

[1957] See 40 CFR 86.1869(a) and 40 CFR XXXXXXX.
[1958] See 49 CFR Part 537.7(c)(7) and 49 CFR Part 531.6 and 533.6.
[1959] Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

technology. Doing so would reduce duplicative efforts for the agencies, as well as manufacturers.[1960]

As mentioned previously, the agencies have decided to allow only new technologies to be added to the ~~picklist~~ menu through the regular rulemaking processes including the opportunity for notice and public comment.

General Motors, DENSO, Global Automakers, and the Auto Alliance further suggested that suppliers should be allowed to request a "grams per mile" value for their off-cycle technologies. They asserted that this will provide certainty to manufacturers before they buy that technology.[1961] Toyota and the Auto Alliance suggested that the agencies could improve efficiency and reduce burdens by creating a "toolbox," methodologies that manufacturers can apply to the analysis of off-cycle credit opportunities.[1962] They stated it would additionally help manufacturers if the agency would issue guidance letters and decision documents for off-cycle credit approvals.[1963]

The agencies believe that developing a "toolbox" may not be possible due to the development of new and emerging technologies, and manufacturers' different approaches for evaluating the benefits of the technologies. The agencies ~~will~~ may consider additional guidance, if feasible, as the program~~s~~ further matures in the approval process of technologies and if the agencies can identify consistent methodologies that may help manufacturers analyze off-cycle technologies.

NCAT and General Motors requested more transparency in the A/C and off-cycle approval process. They suggested that the agencies could provide reports including off-cycle credits approved by vehicle make and model and provide further clarification of data requirements that influenced the decision process.[1964]

EPA and NHTSA have separate approaches for sharing information on these flexibilities, to provide public transparency. EPA already provides detailed information on ~~the~~ manufacturers'~~,~~ generation of A/C and off-cycle credits for each model year in its end of the year compliance report, including the magnitude of credits by manufacturer and by credit type, the

[1960] General Motors, Detailed Comments, NHTSA-2018-0067-11858; Toyota, Detailed Comments, NHTSA-2018-0067-12150; NCAT, Detailed Comments, NHTSA-2018-0067-11969; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Ford, Detailed Comments, NHTSA-2018-0067-11928; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583; DENSO, Detailed Comments, NHTSA-2018-0067-11880; Edison Electric Institute, Detailed Comments, NHTSA-2018-0067-11918; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

[1961] General Motors, Detailed Comments, NHTSA-2018-0067-11858; DENSO, Detailed Comments, NHTSA-2018-0067-11880; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

[1962] Toyota, Detailed Comments, NHTSA-2018-0067-12150; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

[1963] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

[1964] NCAT, Detailed Comments, NHTSA-2018-0067-11969; General Motors, Detailed Comments, NHTSA-2018-0067-11858.

credits generated by technology type, and the penetration of off-cycle technologies in each manufacturer's fleet.[1965] ~~technologies, and credits gained for each model year in its end of the year compliance report.~~ NHTSA plans to share similar information on its PIC and to provide projected data on the market penetration rates of the technologies as soon as it starts receiving information through its new reporting templates for the 2023 compliance model year.

(3) High Efficiency Alternators and Advanced Air Conditioning (A/C) Compressors

EPA sought comments on modifying the off-cycle ~~picklist~~ menu to add certain technologies for which EPA has collected sufficient data to set an appropriate credit level. More specifically, EPA received data from multiple manufacturers on high-efficiency alternators and advanced air conditioning (A/C) compressors that could serve as the basis for new menu credits for these technologies.[1966] EPA requested comments on adding these two technologies to the menu including comments on credit level and appropriate definitions. EPA also requested comments on other off-cycle technologies that EPA could consider adding to the menu including supporting data that could serve as the basis for the credit.

EPA received only supportive comments on its specific request for comments regarding adding high efficiency alternators and advanced A/C compressors to the menu. Toyota, General Motors, BorgWarner, Fiat Chrysler, the Auto Alliance, Global Automakers, MECA, DENSO, SAFE, and Volkswagen submitted responses on the off-cycle ~~picklist~~menu. General Motors, Volkswagen, Fiat Chrysler, Global Automakers, and the Auto Alliance all supported adding high-efficiency alternators and advanced A/C compressors to the ~~picklist~~menu.[1967] They commented that these technologies have already been approved for off-cycle credits through the petition process multiple times. They contend that it would be less burdensome if the technologies would be added to the pre-approved off-cycle credit list. That said, they were concerned about being constrained by the off-cycle caps.[1968]

Commented [A448]: CHANGE AS SHOWN: To provide a more complete explanation of what GHG information EPA makes publicly available.

The agencies believe that adding high-efficiency alternators and advanced A/C compressors to the menu is a reasonable step to help streamline the program by allowing manufacturers to select the menu credit rather than continuing to seek credits through the public approval process. Therefore, EPA is revising the regulations to add these two technologies to the menus. The high-efficiency alternator is being added to the off-cycle credits menu, and the advanced A/C compressor with a variable crankcase valve is being added to the menu for A/C efficiency credits. The credit levels are based on data previously submitted by multiple manufacturers through the off-cycle credits application process, and discussed in the NPRM.

[1965] "The 2018 EPA Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975," EPA-420-R-19-002. March 2019, Figures 5.8 through 5.12, and Tables 5.3 and 5.4.

[1966] https://www.epa.gov/vehicle-and-engine-certification/compliance-information-light-duty-greenhouse-gas-ghg-standards.

[1967] General Motors, Detailed Comments, NHTSA-2018-0067-11858; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

[1968] See, e.g., General Motors, Detailed Comments, NHTSA-2018-0067-11858.

The high efficiency alternator credit is scalable with efficiency, providing an increasing credit value of 0.16 grams/mile CO_2 per percent improvement as the efficiency of the alternator increases above a baseline level of 67 percent efficiency. The advanced A/C compressor credit value is 1.1 grams/mile for both cars and light trucks.[1969]

EPA also received comments from the Auto Alliance, Fiat Chrysler, General Motors, Mitsubishi, Gentherm, ITB, and MEMA on a variety of individual technologies that they suggest adding to the menu.[1970] These commenters provided little data to support their recommended credit levels. The Auto Alliance and Alliance for Vehicle Efficiency further asserted that flexibility mechanisms are increasingly important and there is a need to develop unconventional and non-traditional fuel economy technologies to meet standards.[1971] They requested additional pre-defined and pre-approved technologies to be included in this regulation.[1972]

The agencies have reviewed manufacturers' requests for adding additional technologies to the ~~picklist~~ menu and concluded that there is insufficient data in the record at this time on which to base an appropriate menu credit value for the technologies. Therefore, none of these technologies are being added to the menu at this time. Given the limited data and uncertainty, EPA also does not believe it would be appropriate to add any of the technologies to the menu without an opportunity for public review and comment. Although the agencies are not adding these technologies to the menu at this time, manufacturers may seek off-cycle credits for these technologies through the other program pathways. EPA also notes again that the final standards are not predicated on an expansion of off-cycle credits and therefore EPA's decision of not adding technologies to the menu at this time does not affect the overall feasibility of the standards.

Commented [A449]: CHANGE AS SHOWN: EPA believes it is important to retain this text provided in our earlier draft.

(4) Stop-Start Technology

In 2014, EPA approved additional credits for the Mercedes-Benz's stop-start system through the off-cycle credit process based on data submitted by Mercedes-Benz on fleet idle time and its system's real-world effectiveness (i.e., how much of the time the system turns off the engine when the vehicle is stopped).[1973] Prior to proposal, multiple auto manufacturers requested that EPA revise the table menu value for stop-start technology based solely on one input value

[1969] For additional details regarding the derivation of these credits see EPA's Memorandum to Docket EPA-HQ-OAR-2018-0283 ("Potential Off-cycle Menu Credit Levels and Definitions for High Efficiency Alternators and Advanced Air Conditioning Compressors").

[1970] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073-48; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; General Motors, Detailed Comments, NHTSA-2018-0067-11858; Mitsubishi, Detailed Comments, NHTSA-2018-0067-12056; MEMA, Detailed Comments, MEMA, EPA-HQ-OAR-2018-0283-5692 (See https://www.mema.org/sites/default/files/resource/MEMA%20CAFE%20and%20GHG%20Vehicle%20Comments%20FINAL%20with%20Appendices%20Oct%2026%202018.pdf); ITB, Detailed Comments, EPA-HQ-OAR-2018-0283-5469; Gentherm, Detailed Comments, EPA-HQ-OAR-2018-0283-5058.

[1971] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Alliance for Vehicle Efficiency, Detailed Comments, NHTSA-2018-0067-11696.

[1972] NHTSA-2018-0067-12073-48.

[1973] "EPA Decision Document: Mercedes-Benz Off-cycle Credits for MY 2012-2016," EPA-420-R-14-025 (Sept. 2014).

EPA considered, idle time, in the context of the Mercedes-Benz stop-start system. No manufacturers provided additional data on any of the other factors evaluated during consideration of a conservative credit value for stop-start systems. Stop-start systems vary significantly in hardware, design, and calibration, leading to wide variations in the amount of idle time during which the engine is actually turned off in real-world driving. EPA has learned that some stop-start systems may be less effective in the real-world than the agency estimated in its 2012 rulemaking analysis, for example, due to systems having a disable switch available to the driver, or because stop-start systems can be disabled under certain temperature conditions or auxiliary loads, which would offset the benefits of the higher idle time estimates. EPA requested additional data from manufacturers, suppliers, and other stakeholders regarding a comprehensive update to the stop-start off-cycle credit table value. EPA did not receive any additional real-world system effectiveness data from commenters on which to base an adjusted credit level. MEMA commented that EPA should base an increase in the credit on the agencies' updated estimated effectiveness of stop-start technology in the Draft Technical Assessment Report (TAR), which shows a 67 percent increase in effectiveness.[1974, 1975] However, EPA notes that this estimate is for system effectiveness over the 2-cycle test procedures and, therefore, is not an appropriate basis to adjust the off-cycle credits. The agencies are not adjusting the menu credits for stop-start systems at this time. Manufacturers may apply for additional credits if they are able to collect data demonstrating a system effectiveness that would serve as the basis for those credits.

(5) Menu Credit Cap

The off-cycle menu currently includes a fleetwide cap on credits of 10 grams/mile to address the uncertainty surrounding the data and analysis used as the basis of the menu credits.[1976] Prior to proposal, some stakeholders expressed concern that the current cap may constrain manufacturers' future ability to fully utilize the menu especially if the menu is expanded to include additional technologies, as described above. For example, Global Automakers suggested raising the cap from 10 grams/mile to 15 grams/mile.[1977] EPA requested comments on increasing the current cap, for example, from the current 10 grams/mile to 15 grams/mile to accommodate increased use of the menu. EPA also requested comment on a concept that would replace the current menu cap with an individual manufacturer cap that would scale with the manufacturer's average fleetwide target levels. The cap would be based on a percentage of the manufacturer's fleetwide 2-cycle emissions performance, for example at five to ten percent of CO_2 of a manufacturer's emissions fleet-wide target. With a cap of five percent

[1974] Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022-2025, EPA-420-D-16-900 (July 2016).
[1975] MEMA, EPA-HQ-OAR-2018-0283-5692. See https://www.mema.org/sites/default/files/resource/MEMA%20CAFE%20and%20GHG%20Vehicle%20Comments%20FINAL%20with%20Appendices%20Oct%2026%202018.pdf.
[1976] 40 CFR 86.1869–12(b)(2).
[1977] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.

for a manufacturer with a 2-cycle fleetwide average CO_2 level of 200 grams/mile, for example, the cap would be 10 grams/mile.

There was widespread support from automakers and suppliers for removing the cap entirely or raising the cap from 10 grams/mile to 15-20 grams/mile. Toyota, General Motors, BorgWarner, Fiat Chrysler, the Auto Alliance, Global Automakers, MECA, DENSO, SAFE, and Volkswagen submitted responses on the off-cycle cap to EPA.[1978] They argued that the 2-cycle test does not always account for all the benefits a technology provides.[1979] General Motors, Fiat Chrysler, the Auto Alliance, Global Automakers, and Volkswagen agreed that EPA should remove the 10 grams/mile cap and, if they must keep the cap, increasing it to 15 grams/mile.[1980]

Global Automakers commented that, as more technology receives off-cycle credit values, the cap will restrict innovation and therefore EPA should lift the cap now in anticipation of increased use of technologies.[1981] General Motors similarly commented that the cap was an arbitrary limit without any technical justification and that, if the agency was to add emission reduction technologies to the menu these devices could not be effectively incentivized if the 10 grams/mile cap remains in place, since there would be no room under the cap.[1982] General Motors ~~disagreed with the proposal to provide provisional credits that may be taken away if testing does not fully validate the value of the technology. They~~ suggested that as the program continues, manufacturers will continue to find new technologies and will be limited by the cap. They stated that the cap will stifle additional investments for technologies. MEMA commented that if EPA expands the off-cycle technologies menu and continually adds off-cycle technologies to the menu, it is critical that EPA increase or eliminate the cap on the credits gained from the off-cycle menu.[1983]

Commented [A450]: DELETE: This GM comment was regarding provisional supplier-based credits and does not fit in this section.

The Auto Alliance argued that putting caps on emerging new technologies will hinder further vehicle investments and improvements. The planning cycle is implemented years out and without a guarantee they will see benefits, the Auto Alliance stated that manufacturers lack incentivization to work toward large technological advances.[1984] The Auto Alliance and Alliance

[1978] Toyota, Detailed Comments, NHTSA-2018-0067-12150; General Motors, Detailed Comments, NHTSA-2018-0067-11858; BorgWarner, Detailed Comments, NHTSA-2018-0067-11895; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; MECA, Detailed Comments, NHTSA-2018-0067-11994; DENSO, Detailed Comments, NHTSA-2018-0067-11880; SAFE, Detailed Comments, NHTSA-2018-0067-11981; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1979] See, e.g., DENSO, Detailed Comments, NHTSA-2018-0067-11880.
[1980] General Motors, Detailed Comments, NHTSA-2018-0067-11858; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943; Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032; Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.
[1981] Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.
[1982] General Motors, Detailed Comments, NHTSA-2018-0067-11858.
[1983] MEMA, EPA-HQ-OAR-2018-0283-5692. See https://www.mema.org/sites/default/files/resource/MEMA%20CAFE%20and%20GHG%20Vehicle%20Comments%20FINAL%20with%20Appendices%20Oct%2026%202018.pdf.
[1984] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

for Vehicle Efficiency further asserted that flexibility mechanisms are increasingly important and there is a need to develop unconventional and non-traditional fuel economy technologies.[1985]

ACEEE commented that the off-cycle credit menu cap should not be increased or modified without the agency first defining any other changes it might consider making to the off-cycle credit program and this should be done through a separate NPRM and public review process.[1986] ICCT commented that if the agencies allow more use of off-cycle credits without clear validation of their real-world benefits, the regulations cannot serve their intended objectives to reduce CO_2 and fuel use.[1987]

~~EPA also received a few comments warning about the risks of removing the caps and over incentivizing the CAFE and CO_2 programs. ACEEE pointed out that while expanding and updating the flexibilities that incentivize innovation and research is a great method to increase fuel efficiency, it is important to put a time limit on those incentives and carefully design them so manufacturers do not take advantage. ACEEE argued that, if these flexibilities are not implemented thoughtfully, they can end up reducing the program benefits.[1988] UCS commented that, given the potential interaction from multiple incentives, it is important to consider the combined impacts of flexibilities on the overall stringency of the regulation. UCS stated that given the potential for widespread harm, credits within the program should be severely limited, and the agencies' assessment of the impacts of such incentives should be extremely conservative in order to promote increased environmental benefits of the fuel economy and carbon dioxide emissions standards.[1989]~~

Commented [A451]: DELETE: These comments pertained to incentives such as multipliers rather than the off-cycle program, and are covered in the EPA Compliance preamble section. Recommend deleting here.

The agencies are not increasing the 10 grams/mile menu credit cap at this time. EPA established the 10 grams/mile credit cap to address the uncertainty surrounding the data and analysis used as the basis of the menu credits, and agrees with ACEEE, ICCT, and UCS that sufficient uncertainty remains such that increasing the current cap is not justified. As noted in the 2012 final rule, EPA included the fleet-wide cap because the default credit values were based on limited data, and also because the agencies recognized that some uncertainty is introduced when credits are provided based on a general assessment of off-cycle performance as opposed to testing on the individual vehicle models.[1990] That uncertainty has not significantly diminished since the 2012 final rule. Also, over the course of implementing the program, EPA has encountered issues with the regulatory definitions currently in place for some technologies. The regulations specify that manufacturers may claim credits for technologies that meet the regulatory definitions. However, there have been instances where manufacturers have claimed credits for a technological approach that they have argued meets the regulatory definition, but EPA found that the technology was not implemented consistent with the technological approach envisioned when the off-cycle program was established. This has raised questions of whether the credits for the technological approach in question truly represent real-world reductions, and

[1985] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Alliance for Vehicle Efficiency, Detailed Comments, NHTSA-2018-0067-11696.
[1986] ACEEE, Detailed Comments, NHTSA-2018-0067-12122.
[1987] ICCT, Detailed Comments, NHTSA-2018-0067-11741-43.
~~[1988] ACEEE, Detailed Comments, NHTSA-2018-0067-12122.~~
~~[1989] UCS, Detailed Comments, NHTSA-2018-0067-12039.~~
[1990] 77 FR 62834 (Oct. 15, 2012).

whether the credits should ultimately be allowed. These types of issues have resulted in uncertainty, which can lead to delays in credit calculations, competitive inequities, as well as increased burden on the agency to review and resolve issues. The caps continue to serve as an important measure against the loss of emissions reductions and fuel savings given the uncertainty in the credit values as the program is implemented. Since the agencies are not expanding the menu beyond the two technologies discussed above, the agencies believe there remains enough room under the cap such that the menu may continue to serve its purpose as a source of off-cycle credits. Although a few manufacturers approached the cap limit in MY 2018, the fleet average menu credit was 4.7 grams/mile, less than half the cap value.[1991] If the agencies undertake a rulemaking in the future to modify the menu or regulatory definitions, the agencies may re-evaluate the cap levels at that time. The agencies note that the cap only applies to credits based on the menu. Under the current program, manufacturers may apply for credits beyond the cap through other available pathways based on a demonstration of off-cycle technology emission reduction data for their fleets.

As noted above, ~~T~~the agencies have decided to continue the option to add technologies to the menu only through the rulemaking process and, for this final rule, have decide to add two new ~~picklist~~ menu items~~:~~ one for high-efficiency alternators and another for advanced A/C compressors. ~~No further incentives are being adopted for advanced technology vehicles as discussed previously.~~ The agencies stated that they will only add technologies when sufficient data has been collected from multiple manufacturers and vehicle models on which to base a menu credit. Accordingly, the agencies believe this approach ensures that conservative, robust and accurate credit levels are being added representing vehicles "on average" across the fleet.

Commented [A452]: CHANGE AS SHOWN: EPA recommends deleting because this seems out of place in an off-cycle section and implies that AC and off-cycle credits are advanced technology incentives which they are not.

Also not accurate due to new incentives for NGVs.

Finally, ~~the agencies have~~NHTSA has been studying how the combination of flexibilities and incentives may adversely affect the stringency of ~~CO_2 and~~the CAFE regulations. ~~The agencies are~~NHTSA is aware of an instance in which combining incentives for alternative fueled vehicles and ~~incentives~~ adjustments for A/C and off-cycle technologies allowed one manufacturer to increase in CAFE fleet performance to a combined average of 516.8 mpg for MY 2017, a curious result. ~~EPA and~~ NHTSA ~~are~~ is continuing to evaluate the issue of combining incentives and flexibilities and may address this issue further in the future.

Commented [A453]: DELETE OR REVISE: EPA does not agree with this characterization. This seems out of place in the off-cycle section since this result for Tesla is mostly from the EV alternative fuel calculation (0.15 divisor) for CAFE rather than from the AC and off-cycle adjustments. This result is not "curious" or unexpected and is consistent with the regulations which are being implemented as they were intended. Any future change to the calculations would impact all EV manufacturers, not just Tesla.

EPA prefers to delete this paragraph, but if this text is retained, it should be in NHTSA's voice alone.

(6) Eligibility

Though, in the NPRM, EPA did not explicitly request comment on the eligibility criteria for determining what technologies are eligible for off-cycle credits, EPA received comments on this topic. UCS commented that regulations should be clarified so that the program does not result in unwarranted credits for baseline technologies, noting that in the 2012 final rule EPA stated that technologies integral or inherent to the basic vehicle design were not eligible for credits and specifically excluded technologies identified by the agency as technologies a manufacturer may use to meet the two-cycle CO_2 standards.[1992] ACEEE commented that off-

[1991] The 2018 EPA Automotive Trends Report, Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975, EPA-420-R-19-002 (Mar. 2019).
[1992] UCS, Detailed Comments, NHTSA-2018-0067-12039.

cycle credits should be limited to new and innovative technologies and, that to be eligible for credit, a technology must reduce emissions from the vehicle receiving the credit (as opposed to other vehicles on the road, for example, through system effects of technologies designed for crash avoidance or improving traffic flow).[1993] The Auto Alliance also commented in the area of eligibility, suggesting regulatory changes that would allow off-cycle credits for any technology where the manufacturer could demonstrate an off-cycle emissions benefit.[1994] The Auto Alliance commented that the program is intended to provide credit for technologies that provide more fuel economy and CO_2 emissions reduction benefit in the real-world than is realized in FTP and HFET on-cycle testing and that a baseline technology should be eligible for such credits.

Given the various public comments on eligibility of technologies for off-cycle credits, the agencies are clarifying the regulations regarding technology eligibility, consistent with the intent and EPA's interpretation of the 2012 rule, as expressed in the preamble to the proposed and final rules. The agencies believe that clarifying the regulations will reduce confusion among manufacturers as to what technologies are eligible and reduce the overall program burden associated with EPA staff giving continued guidance to manufacturers regarding eligibility, as detailed in the 2012 rule preamble. Eligibility was thoroughly addressed in the 2012 final rule preamble, but the regulations were not as clear, which has led to confusion on the part of some manufacturers and delays in reviewing credit applications.[1995] The agencies are not establishing a new policy regarding eligibility, only amending the language reflecting the existing policy in the regulations for sake of clarity.

As noted in the 2012 final rule preamble, the goal of the off-cycle credits program is to provide "an incentive for the development and use of additional technologies to achieve real-world reductions in CO_2 emissions."[1996] EPA further stated that the intent of the program is to "provide an incentive for CO_2 and fuel consumption reducing off-cycle technologies that would otherwise not be developed because they do not offer a significant 2-cycle benefit."[1997] The regulation at 40 CFR 86.1869-12(a) provides that manufacturers may generate credits for CO_2 reducing technologies "where the CO_2 reduction benefit for the technology is not adequately captured on the Federal Test Procedure and/or Highway Fuel Economy Test." The regulation continues: "[t]hese technologies must have a measurable, demonstrable, and verifiable real-world CO_2 reduction that occurs outside the conditions of the Federal Test Procedure and the Highway Fuel Economy Test."

Off-cycle credits are available for technologies that are not utilized when performing FTP and HFET tests because their operation is linked to a condition not found during the 2-cycle testing. For example, heating and cooling systems are not operated during the 2-cycle test, and therefore, efficiency improvements to these systems are not captured at all on the 2-cycle tests. As the 2012 rule's language indicates, off-cycle credits are not necessarily limited to technologies listed on the menu or off-cycle technologies with no measurable benefit on the FTP and/or HFET. Off-cycle credits may be available for some technologies whose performance is

[1993] ACEEE, Detailed Comments, NHTSA-2018-0067-12122.
[1994] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[1995] 77 FR 62726-36, 62835-37.
[1996] 77 FR 62833.
[1997] 77 FR 62836.

measurable to some extent on the FTP and/or HFET but which perform measurably better off-cycle. Active aerodynamic and stop-start technologies (menu item) are examples. However, there are limits on what the agencies would consider to be an off-cycle technology eligible for credits, as discussed below.

Just as the regulations and preamble to the 2012 final rule listed technologies that the agencies considered to be off-cycle technologies, the preamble also discussed technologies that the agency would not consider off-cycle technologies—i.e., technologies the agencies consider to be "adequately captured" by the FTP and therefore not eligible for off-cycle credits. The preamble specifically noted that engine, transmission, mass reduction, passive aerodynamic design, and base tire technologies are not considered to be off-cycle technologies eligible for credits.[1998] These are technologies that are considered to be "integral or inherent to basic vehicle design."[1999] In response to comments in the final rule, the agencies further clarified that advanced combustion concepts, such as camless engines, variable compression ratio engines, micro air/hydraulic launch assist devices, would not be considered to be eligible for credits.[2000] This limitation to eligibility further extends to other engine designs, transmission designs, and electrification systems not specifically contemplated in the rulemaking, such as Atkinson combustion engines, and 9 and 10 speed transmissions, as well as to other hybrid systems such as 48 Volt technologies. Further, the 2012 final rule preamble stated that technologies included in the agencies' assessment for purposes of developing the standard would not be allowed to generate off-cycle credits and cites the technologies described in Chapter 3 of the 2012 final rule TSD.[2001] Finally, off-cycle credits are not available for technologies required to be used by Federal Law or for crash avoidance systems, safety critical systems, or technologies that may reduce the frequency of vehicle crashes.[2002]

The preamble to the 2012 final rule provides the rationale for what the agency considers an off-cycle technology and, therefore, eligible for credits. Technologies that are integral or inherent to the vehicle are, by necessity, well represented on the 2-cycle test.[2003] Examples provided in the preamble are engine, transmission, mass reduction, passive aerodynamic design, and base tire technologies. The control logic for these powertrain components, like the components themselves (i.e. engine and transmission), are constantly active, fully functioning, and operating over the entirety of the FTP and HFET. Similarly, an automatic transmission, regardless of whether it has 6-speeds or 8-speeds, would still be constantly active, fully functioning and operating over the entirety of the FTP and HFET.[2004] This would also be true for base engine technologies, advanced combustion concepts, engine components (pistons, valves,

[1998] 77 FR 62732, 62836.
[1999] 77 FR 62732, 62836/1; 81 FR 73499.
[2000] 77 FR 62732.
[2001] 77 FR 62836.
[2002] 40 CFR 86.1869-12(a); 77 FR 62836.
[2003] 77 FR 62732, 62836.
[2004] 76 FR 75024 (Dec. 1, 2011).

camshafts, crankshafts, oil pumps, etc.), and driveline components (individual components of the transmission, axle, and differential).[2005]

Further, even if these technologies have greater benefits on supplemental test cycles, EPA has explained that it would be difficult to devise accurate A/B testing (i.e., with and without the technology) for these technologies.[2006] The 2012 preamble states that "EPA is limiting the off-cycle program to technologies that can be identified as add-on technologies conducive to A/B testing," partly because it would be very difficult accurately to parse out the off-cycle benefits for some integral technologies.[2007] Because the technology is integral to the vehicle, there would not be an appropriate baseline (i.e., without the technology) vehicle to use for comparison. Vehicles are not built without tires, engines, passive aerodynamics or transmissions.

Also, because these technologies are inherent to the vehicle design, their performance is already reflected in the stringency of the standard and giving credits for these inherent technologies would be a type of double-counting windfall.[2008] "[S]ince these methods are integral to basic vehicle design, there are fundamental issues as to whether they would ever warrant off-cycle credits. Being integral, there is no need to provide an incentive for their use, and (more importantly), these technologies would be incorporated regardless. Granting credits would be a windfall."[2009] As such, EPA has laid out a clear basis that technological improvements to integral and inherent components are considered to be adequately captured on the FTP and HFET test.

EPA is clarifying the regulations in a manner that is consistent with the intent and our interpretation of the 2012 rule, as expressed in the preambles to the proposed and final rules. The regulations are revised to specify that technologies used primarily to meet the 2-cycle standards are not eligible for off-cycle credits and that only technologies primarily installed for reducing off-cycle emissions would be eligible. The revised regulations specify that the technologies must not be integral or inherent to the basic vehicle design, such as, for example, engine, transmission, mass reduction, passive aerodynamic design, and tire technologies. Exceptions to these general provisions include technologies already specified on the menu, including engine idle stop-start, active aerodynamic improvements, and high-efficiency alternators. These technologies may provide some benefit on the 2-cycle test, but EPA determined in the 2012 rule that they are eligible for off-cycle credits because they are technologies that could be added to vehicles to provide discernable off-cycle reductions.

Regulatory text at 40 CFR 86.1869–12(a) states: "Manufacturers may generate credits for CO_2 reducing technologies where the CO_2 reduction benefit of the technology is not adequately captured on the Federal Test Procedure and/or the Highway Fuel Economy Test," to which EPA is adding, "such that the technology would not be otherwise installed for purposes of reducing emissions (directly or indirectly) over those test cycles (i.e., on-cycle) for compliance with the [CO_2] standards." EPA is also adding text to this paragraph of the regulations specifying: "The

[2005] 77 FR 62732/2.
[2006] 76 FR 75024.
[2007] 77 FR 62836.
[2008] 77 FR 62732.
[2009] See also 76 FR 75024.

technologies must not be integral or inherent to the basic vehicle design, such as engine, transmission, mass reduction, passive aerodynamic design, and tire technologies. Technologies installed for non-off-cycle emissions related reasons are also not eligible as they would be considered part of the baseline vehicle design. The technology must not be inherent to the design of occupant comfort and entertainment features except for technologies related to reducing passenger A/C demand and improving A/C system efficiency. Notwithstanding the provisions of this paragraph (a), off-cycle menu technologies included in paragraph (b) of this section remain eligible for credits."

The agencies believe the above regulatory changes will help reduce confusion over what technologies are eligible for off-cycle credits, refocusing the program on technologies that manufacturers would install on vehicles for purposes of reducing off-cycle emissions rather than obtaining additional credits for technologies installed primarily for 2-cycle emissions reduction or for other reasons not related to emissions. This approach is consistent with the intent of the program as stated in the 2012 final rule to provide an incentive to develop and employ off-cycle technologies not adequately captured on the 2-cycle test procedure.

Of the technologies recommended by manufacturers to be added to the menu, cooled EGR is an example of a technology that would not be eligible because it is an integral 2-cycle technology that EPA noted in its technology assessment in the MY 2012 rule. Cooled EGR is often an integral component of turbo charged gasoline direct injection engines which is a primary CO_2 reduction strategy used by manufacturers to reduce 2-cycle emissions. The technologies are calibrated to act as a system such that is not possible to separate them in a way that would allow for a clear indication of the off-cycle benefit of cooled EGR as a stand-alone technology.

EPA also received comments from the Auto Alliance regarding several technologies they believe should qualify as active warm-up off-cycle technologies. The Auto Alliance commented that systems that use waste heat from the exhaust gas stream should receive additional credits beyond the menu credits currently established for active engine and transmission warm-up.[2010] However, when EPA established the menu credits for active transmission and engine warm-up in the 2012 rule, EPA envisioned waste heat from the exhaust as the primary source of heat to quickly bring the system to operating temperature as the basis for the warm-up technology credits.[2011] Therefore, EPA does not believe additional credits, as suggested by the Auto Alliance, are warranted. EPA further notes that the definitions for active engine and transmission warm-up specify that "waste heat" be used in active warm-up technologies in order to qualify for the credits.[2012] If a system first directs heat to warm the engine oil or warm the interior cabin, and only then to the engine or transmission, thereby delaying active warm-up, EPA would not view that heat as waste heat since it is serving other purposes during initial vehicle warm-up. EPA would also not consider this approach to be warming up the engine or transmission "quickly" due to the potentially significant delay in warm-up activation. In developing the active warm-up credits, EPA focused on systems using heat from the exhaust as a

[2010] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[2011] See Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, EPA-420-R-12-901, August 2012, p. 5-96 - 5-100.
[2012] 40 CFR 86.1869–12(b)(4)(v) and (vi).

primary source of waste heat because that heat would be available quickly and also be exhausted by the vehicle and otherwise unused.

EPA allowed for the possible use of other sources of heat such as coolant as the basis for credits as long as those methods would "provide similar performance" as extracting the heat directly from the exhaust system.[2013] However, EPA may require manufacturers to demonstrate that the system is based on "waste heat" or heat that is not being preferentially used by the engine or other systems to warm-up other areas like engine oil or the interior cabin. Systems using waste heat from the coolant do not qualify for credits if their operation depends on, and is delayed by, engine oil temperature or interior cabin temperature. As the engine and transmission components are warming up, the engine coolant and transmission oil do not have any 'waste' heat available for warming up anything else on the vehicle. During engine and transmission warm-up, the only waste heat source in a vehicle with an internal combustion engine is the engine exhaust as the transmission and coolant have not reached warmed-up operating temperature and therefore do not have any heat to share. Conserving heat in a transmission is not a rapid transmission warm-up using waste heat. Unless the component with lubricating oil and coolant is operating at its fully warmed-up design temperature, by EPA's definition, that component does not have any waste heat available for transfer from the lubricating oil or coolant to any other device until it has reached its fully warmed-up operating temperature (i.e. the temperature when the cooling system is enabled). A qualifying system may involve a second cooling loop that operates independent of the primary coolant system and is not dependent on or otherwise delayed by, for example, cabin temperature. Evaluating whether such systems qualify for menu credits often requires additional information regarding system design to understand better how the system uses waste heat. Given the complexity of these systems and the need to sometimes consider the details of how a system operates, EPA is not making any changes to the menu regarding warm-up technologies.

The Auto Alliance further commented that active transmission bypass valves should qualify for active transmission warm-up credits.[2014] The Auto Alliance commented that traditional transmission oil coolers are always active and sized for extreme or worst-case hot ambient conditions. The coolers will, in colder ambient conditions, keep the transmission temperatures well outside of their most efficient operating range. The bypass valve circumvents the cooler when the transmission is relatively cold preserving the transmission heat, so the transmission warms more quickly. EPA disagrees that this type of approach should be eligible for active transmission warm-up because it does not use waste heat to add heat to the transmission. Instead, it prevents useful heat already present in the transmission from being unnecessarily removed. Also, EPA does not view this type of bypass valve as an off-cycle technology but rather as part of a good engineering design of a transmission cooler system. Many vehicles already are designed with transmission cooler bypass valves. EPA does not believe existing coolers qualify as warm-up technologies simply because they are disabled under

[2013] See Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, p. 5-99, EPA-420-R-12-901, August 2012.
[2014] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.

cold conditions. This approach does not represent the addition of a new off-cycle warm-up technology but the disabling of an existing cooling technology.

Although the agencies did not consider changes to the program to allow credits for safety-related technologies and autonomous vehicle technologies in the proposal, comments were received both in favor of and not in favor of allowing such credits.[2015] The agencies note that the rationale for not allowing off-cycle credits for safety-related or crash avoidance technologies has not changed since the 2012 rule and, therefore, in the proposed rule the agencies did not consider making any changes to allow off-cycle credits for safety-related technologies.[2016] The agencies continue to believe that there is a very significant distinction between technologies providing direct and reliably quantifiable improvements to fuel economy and CO_2 emission reductions, and technologies which provide those improvements by indirect means, where the improvement is not reliably quantifiable, and may be speculative (or in many instances, non-existent), or may provide benefit to other vehicles on the road more than for themselves. The agencies also continue to believe that the advancement of crash-related and crash avoidance systems specifically is best left to NHTSA's exercise of its vehicle safety authority.

Auto manufacturers and suppliers also commented that EPA should adopt "eco-innovation" credits approved in the European Union (EU) vehicle CO_2 reduction program as part of the off-cycle credits program.[2017] No data was provided as to why the credits would be appropriate for the U.S. vehicle fleet. EPA did not consider or request comment on the EU credits program and does not believe the credit levels would necessarily be appropriate for the U.S. fleet given the very different vehicle use and driving patterns between Europe and the U.S. Thus, there is no assurance that the credits would be based on real-world emissions reductions.

EPA received comments from the Auto Alliance and Global Automakers that EPA should automatically award credits if the agency does not take final action within 90 days of receiving a request for credits.[2018] Regarding these comments, EPA does not believe such a provision is in keeping with maintaining the integrity of the off-cycle credits program. As discussed above, EPA often requires time to sort through complex issues to determine if the technologies meet the regulatory requirements for receiving credits and whether the credits have been quantified appropriately. In some instances, EPA has received public comments and manufacturer rebuttals to those comments that takes additional time to consider before making a final decision. EPA's goal continues to be to evaluate applications for credits in as timely a manner as is possible given the issues that must be addressed and within the resources available. While EPA's need carefully to consider applications may slow down the approval process or result in credits not being approved, it remains paramount to ensure credits are not provided to technologies that do not provide actual off-cycle benefits, and thereby do not meet the regulations. In the past, longer time frames for EPA review have not caused manufacturers to

[2015] See, e.g., SAFE, Detailed Comments, NHTSA-2018-0067-11981; AAA, Detailed Comments, NHTSA-2018-0067-11979.
[2016] 77 FR 62733.
[2017] See, e.g., Mitsubishi, Detailed Comments, NHTSA-2018-0067-12056.
[2018] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Global Automakers, Detailed Comments, NHTSA-2018-0067-12032.

lose credits where credits are determined by EPA to be warranted under the regulations. EPA believes that the changes EPA is making to the program will help streamline the program and reduce confusion, thus helping to reduce the time necessary to evaluate applications and provide final decisions to manufacturers.

(7) Supplier Role in the Off-Cycle Credits Program

Prior to proposal, EPA heard from many suppliers and their trade associations about an interest in allowing suppliers to have a formal, regulatorily defined role in the off-cycle credits program.[2019] EPA requested comment on providing a pathway for suppliers, along with at least one auto manufacturer partner, to submit off-cycle applications for EPA approval. As described in the proposal, under such an approach, an application submitted by a supplier and vehicle manufacturer would establish a credit and/or methodology for demonstrating credits that all auto manufacturers could then use in their subsequent applications. EPA requested comment on requiring that the supplier be partnered in a substantive way with one or more auto manufacturers to ensure that there is a practical interest in the technology prior to EPA investing resources in the approval process. The supplier application would be subject to public review and comment prior to an EPA decision. However, once approved, subsequent auto manufacturer applications requesting credits based on the supplier methodology would not be subject to public review. Under this ~~proposal~~concept, the credits would be available provisionally for a limited period of time, allowing manufacturers to implement the technology and collect data on their vehicles in order to support a continuation of credits for the technology in the longer term. Also, as envisioned by EPA in its request for comment, ~~The proposal would also provide that~~ the provisional credits could be included under the menu credit cap since they would be based on a general analysis of the technology rather than manufacturer-specific data.

Commented [A454]: **CHANGE AS SHOWN:** EPA only requested comment.

Auto manufacturers' and suppliers' comments were generally supportive of an expanded role for suppliers in the off-cycle credit program. The Auto Alliance supported allowing a supplier to lead the application process but did not support the provisional credit concept since the follow-up testing conducted by manufacturers may not support the level of credits initially claimed by the supplier, resulting in a lower than anticipated credit.[2020] Instead, the Auto Alliance suggested a separate cap for supplier-based credits and noted that manufacturers could submit their own data if they wanted to pursue credits levels that exceeded the cap. General Motors similarly disagreed with the provisional credits that might be rescinded if subsequent testing does not fully validate the value of the technology.[2021] MEMA supported the request for comments regarding a supplier-led process but did not support requiring that suppliers have an auto manufacturer partner.[2022] MEMA commented that there would be no incentive for a supplier to go through the product/technology development process, collect the necessary data,

[2019] 83 FR 43461.
[2020] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[2021] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.
[2022] MEMA, EPA-HQ-OAR-2018-0283-5692. See https://www.mema.org/sites/default/files/resource/MEMA%20CAFE%20and%20GHG%20Vehicle%20Comments%20FINAL%20with%20Appendices%20Oct%2026%202018.pdf.

and undertake the full application process for a product/technology that would not generate manufacturer interest.

EPA is not adopting revisions to the regulations to broaden the role of suppliers in the off-cycle credit program at this time. EPA believes such an approach would require additional study and comments regarding the appropriate means of integrating manufacturer data with supplier data in order to ensure the validity of the credits and the integrity of the program. In light of these issues, EPA believes additional discussions with interested parties and an opportunity for public comment, both of which are beyond the scope of this rulemaking, are needed. EPA continues to believe such an approach could encourage the further development of off-cycle technologies, but must be done in a reasonable way that ensures the credits are based on real-world emissions reductions. Under the approach suggested by the Auto Alliance, manufacturers could claim supplier-based credits indefinitely and EPA may never receive any manufacturer data substantiating the credits unless that data supported a credit that exceeded that established through the supplier process. EPA is concerned such a one-way ratchet approach may result in the loss of emissions benefits and undermining the integrity of the off-cycle credit program. EPA also remains concerned about the increased volume of credit applications EPA would need to evaluate including potentially frivolous requests making dubious claims regarding emissions benefits for technologies that manufacturers would have no interest in using. EPA understands MEMA's perspective on the issue of requiring a manufacturer partner, but a supplier-only process would potentially open the door to many requests such that the agency would need to expend considerable additional resources. EPA notes that nothing in the current regulations prevents collaboration between manufacturers and suppliers. Suppliers can and do team with a manufacturer to support the manufacturer's application for credits including providing supporting data and analysis.

c) Final Decisions on the 2016 Alliance/Global Petition

(1) Retroactive A/C and Off-Cycle CAFE adjustments

In 2016, the Alliance and Global submitted a petition for rulemaking, which included requests that: (1) NHTSA allow retroactive credits for A/C and off-cycle incentives for MYs 2012 to 2016; and (2) NHTSA and EPA revisit the average A/C efficiency benefit calculated by EPA applicable to MYs 2012 through 2016. The Alliance/Global argued that A/C efficiency improvements were not properly acknowledged in the CAFE program, and that manufacturers had exceeded the A/C efficiency improvements estimated by the agencies. The petitioners requested that EPA also amend its regulations such that manufacturers would be entitled to additional A/C efficiency improvement benefits retroactively. The petitioners also argued that NHTSA incorrectly stated the agency had taken off-cycle adjustments into consideration when setting standards for MYs 2017 through 2025, but not for MYs 2010-2016. The Alliance/Global further contended that because neither NHTSA nor EPA considered off-cycle adjustments in formulating the stringency of the MY 2012-2016 standards, NHTSA should retroactively grant manufacturers off-cycle adjustments for those model years as EPA did. Doing so, they said, would maintain consistency between the agencies' programs.

Of the two agencies, EPA was the first to establish an off-cycle technology program. For MYs 2012 through 2016, EPA allowed manufacturers to request off-cycle credits for "technologies that achieve [CO_2] reductions that are not reflected on current test procedures…"[2023] In the subsequent MY 2017 and later rulemaking, NHTSA joined EPA and included an off-cycle program for CAFE compliance. The Alliance/Global petition cited a statement in the MYs 2012-2016 final rule as affirmation that NHTSA took off-cycle adjustments into account in formulating the MYs 2012-2016 stringencies, and therefore should allow manufacturers to earn off-cycle benefits in model years that have already passed.

In the NPRM, NHTSA tentatively decided to retain the structure of the existing A/C efficiency program and not extend it to MYs 2010 through 2016. For the rulemaking for MYs 2012 through 2016, NHTSA determined it was unable to consider improvements manufacturers made to passenger car A/C efficiency in calculating CAFE compliance.[2024,2025] However, EPA did consider passenger car improvements to A/C efficiency for that timeframe. To allow manufacturers to build one fleet that complied with both EPA and NHTSA standards, the CAFE and CO_2 standards were offset to account for the differences borne out of A/C efficiency improvements. Specifically, the agencies converted EPA's grams/mile standards to NHTSA mpg (CAFE) standards. EPA then estimated the average amount of improvement manufacturers were expected to earn via improved A/C efficiency. From there, NHTSA took EPA's converted mpg standard and subtracted the average improvement attributable to improvement in A/C efficiency. NHTSA set its standard at this level to allow manufacturers to comply with both standards with similar levels of technology.[2026]

Likewise, EPA tentatively decided in the NPRM not to modify its regulations to change the way to account for A/C efficiency improvements. EPA believed this was appropriate as manufacturers decided what fuel economy-improving technologies to apply to vehicles based on the standards as finalized in 2010.[2027] This included deciding whether to apply traditional tailpipe technologies, A/C efficiency improvements, or both. Granting A/C efficiency adjustments to manufacturers retroactively could result in arbitrarily varying levels of adjustments granted to manufacturers, similar to the Alliance/Global request regarding retroactive off-cycle adjustments. Thus, the existing A/C efficiency improvement structure for MYs 2010 through 2016 ~~will~~ would remain unchanged.

NHTSA also tentatively decided manufacturers should not be granted retroactive off-cycle adjustments for MYs 2010 through 2016, and presented a number of clarifications to justify the denial. In particular, Alliance/Global pointed to a general statement where NHTSA, while discussing consideration of "the effect of other motor vehicle standards of the Government

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[2023] 75 FR 25341, 25344 (May 7, 2010). EPA had also provided an option for manufacturers to claim "early" off-cycle credits in the 2009-2011 time frame.

[2024] At that time, NHTSA stated "[m]odernizing the passenger car test procedures, or even providing similar credits, would not be possible under EPCA as currently written." 75 FR 25557 (May 7, 2010).

[2025] 74 FR 49700 (Sept. 28, 2009).

[2026] *Id.*

[2027] In the MY 2017 and later rulemaking, NHTSA reaffirmed its position it would not extend A/C efficiency improvement benefits to earlier model years. 77 FR 62720 (Oct. 15, 2012).

on fuel economy," stated that that rulemaking resulted in consistent standards across the program.[2028] The Alliance/Global petition took this statement as a blanket assertion that NHTSA's consideration of all "relevant technologies" included off-cycle technologies. To the contrary, as quoted above, NHTSA explicitly stated it had not considered these off-cycle technologies.[2029]

The fact that NHTSA had not taken off-cycle adjustments into consideration in setting its MYs 2012-2016 standards makes granting the Alliance/Global request inappropriate. Doing so could result in a question as to whether the MY 2012-2016 standards were maximum feasible under 49 U.S.C. 32902(b)(2)(B). If NHTSA had considered industry's ability to earn off-cycle adjustments—an incentive that allows manufacturers to utilize technologies other than those that were being modeled as part of NHTSA's analysis—the agency might have concluded more stringent standards were maximum feasible. Additionally, granting off-cycle adjustments to manufacturers retroactively raises questions of equity. NHTSA issued its MYs 2012-2016 standards without an off-cycle program, and manufacturers had no reason to anticipate that NHTSA would allow the use off-cycle technologies to meet fuel economy standards. Therefore, manufacturers made fuel economy compliance decisions with the expectation that they would have to meet fuel economy standards using on-cycle technologies. Generating off-cycle adjustments retroactively would arbitrarily reward some (and potentially disadvantage other) manufacturers for compliance decisions they made without the knowledge such technologies would be eligible for NHTSA's off-cycle program. Thus, NHTSA tentatively decided to deny Alliance/Global's request for retroactive off-cycle adjustments.

It is worth noting that in the MYs 2017 and later rulemaking, NHTSA and EPA did include off-cycle technologies in establishing the stringency of the standards. As Alliance/Global noted, NHTSA and EPA limited their consideration to stop-start and active aerodynamic features because of limited technical information on these technologies.[2030] At that time, the agencies stated they "have virtually no data on the cost, development time necessary, manufacturability, etc. [sic] of these technologies. The agencies thus cannot project that some of these technologies are feasible within the 2017-2025 timeframe."[2031]

As described above, NHTSA first allowed manufacturers to generate off-cycle technology fuel consumption improvement values equivalent to CO_2 off-cycle credits in MY 2017.[2032] In finalizing the rule covering MYs 2017 and later, NHTSA declined to retroactively extend its off-cycle program to apply to model years 2012 through 2016,[2033] explaining "NHTSA

[2028] *Id.*

[2029] Likewise, EPA stated it had not considered off-cycle technologies in finalizing the MYs 2012-2016 rule. "Because these technologies are not nearly so well developed and understood, EPA is not prepared to consider them in assessing the stringency of the CO_2 standards." *Id.* at 25438.

[2030] Alliance/Global Petition at 7.

[2031] Draft Joint Technical Support Document: Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards (November 2011), p. 5-57.

[2032] 77 FR 62840 (Oct. 15, 2012).

[2033] See *id.*; EPA decided to extend provisions from its MY 2017 and later off-cycle program to the 2012-2016 model years.

did not take [off-cycle credits] into account when adopting the CAFE standards for those model years. As such, extending the credit program to the CAFE program for those model years would not be appropriate."[2034]

In the NPRM, NHTSA and EPA sought any further comments on the tentative denials of the retroactive requests in the Alliance/Global. The Auto Alliance and Fiat Chrysler provided additional comments on the tentative denial of the petition requests from the Alliance/Global. The commenters cited that the widening gap between the regulatory standards and actual industry-wide new vehicle average fuel economy that has become evident since 2016, despite the growing use of improvement "credits" from various flexibility mechanisms, such as off-cycle technology credits, mobile air conditioner efficiency credits, mobile air conditioner refrigerant leak reduction credits and credits from electrified vehicles.[2035] The commenters believe that applying retroactive credits for the new flexibilities for MYs 2012 to 2016 can address the current compliance deficiencies.

Upon consideration of the issue, NHTSA is finalizing its decision to deny any retroactive off-cycle adjustments in the CAFE program for MYs 2012-2016. As mentioned in the NPRM, NHTSA is concerned about the negative impact of allowing retroactive credits, which could undermine the stringency of the MYs 2012-2016 standards. EPA is finalizing its decision not to modify its regulations to change the benefits for A/C efficiency improvements. As mentioned by EPA, the current approach creates uniformity and objectivity in determining A/C efficiency benefits. Consequently, because EPA is maintaining the current A/C determination methodology and NHTSA already considered those A/C adjustments in its MYs 2012-2016 CAFE standards, NHTSA is also finalizing its decisions in this rule to deny any retroactive A/C adjustments in the CAFE program for MYs 2012-2016.

(2) Petition Requests on A/C Efficiency and Off-Cycle Program Administration

As discussed above, NHTSA and EPA jointly administer the off-cycle program. The 2016 Alliance/Global petition requested that EPA and NHTSA make various adjustments to the off-cycle program; specifically, the petitioners requested that the agencies should:

- re-affirm that technologies meeting the stated definitions are entitled to the off-cycle credit at the values stated in the regulation;
- re-acknowledge that technologies shown to generate more emissions reductions than the pre-approved amount are entitled to additional credit;
- confirm that technologies not in the null vehicle set but which are demonstrated to provide emissions reductions benefits constitute off-cycle credits; and
- modify the off-cycle program to account for unanticipated delays in the approval process by providing that applications based on the 5-cycle methodology are to be

[2034] *Id.*

[2035] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073; Fiat Chrysler, Detailed Comments, NHTSA-2018-0067-11943.

deemed approved if not acted upon by the agencies within a specified timeframe (for instance 90 days), subject to any subsequent review of accuracy and good faith.[2036]

With respect to Alliance/Global's request regarding off-cycle technologies that demonstrate emissions reductions greater than what is allowable from the menu, this final rule retains that capability. As was the case for MYs 2017-2021, a manufacturer may still apply for FCIVs and CO_2 credits beyond the values listed on the menu, provided the manufacturer demonstrates the CO_2 and fuel economy improvement.[2037] This includes the two-alternative processes for demonstrating CO_2 reductions and fuel economy improvement for gaining benefits using either the 5-cycle or alternative approval methodologies.[2038]

The agencies have considered Alliance/Global's requests to streamline aspects of the A/C efficiency and off-cycle programs in response to the issues outlined above. Among other things, Alliance/Global requested that the agencies consider providing for a default acceptance of petitions for off-cycle credits after a specified period of time, provided that all required information has been provided, to accelerate the processing of off-cycle credit requests. While the agencies agree with the merits of~~that the~~ A/C efficiency and off-cycle ~~program should incorporate~~ programmatic improvements, there are significant concerns with the concept of approving petition requests by default because such requests may not address program issues like uncertainty in quantifying program benefits, or general program administration.

Based on its consideration of the issues raised by the Alliance/Global, EPA has adopted in this final rule new processes for streamlining the compliance mechanisms for approving off-cycle and ~~A/C petition~~applications as discussed in the preceding section.

d) Specialty Vehicles with Low Mileage (SVLM)

In response to the NPRM, Volkswagen submitted comments seeking to adopt a new flexibility for specialty vehicles with low mileage (SVLM).[2039] The flexibility would apply to specialty vehicles produced at low volumes and produced for infrequent use. They argued these specialty vehicles do not approach the vehicle miles traveled of typical vehicles. They requested that NHTSA and EPA allow the SVLM flexibility for vehicles that demonstrate limited predicted driving use. The flexibility would allot each manufacturer a limited annual production of 5,000 SVLM vehicles. It was also proposed that, within this limited product volume, each SVLM would retain its footprint derived performance target (per model type), but would utilize a modified VMT for determining any credits or debits associated with the performance of these vehicles within the manufacturer's fleet.

The agencies have considered the request from Volkswagen for credits or debits and fuel economy adjustments for SVLM vehicles and are denying the request. ~~The agencies~~NHTSA notes that Congress prescribed alternative (reduced) CAFE standards for low-volume

[2036] Alliance/Global Petition at 20.
[2037] 77 FR 62837 (Oct. 15, 2012).
[2038] 40 CFR 86.1869-12.
[2039] Volkswagen, Detailed Comments, NHTSA-2017-0069-0583.

manufacturers, codified in 49 CFR part 525. Low-volume manufacturers' vehicles are often high-end sports cars ~~which do not have significant fuel savings technologies and are not typically driven by their owners for long distances~~. Congress limited this exemption under the CAFE program to manufacturers of fewer than 10,000 passenger automobiles.[2040] EPA has a ~~parallel~~similar program for ~~low-~~small volume manufacturers which are defined as manufacturers with average sales for the three most recent consecutive model years of less than 5,000 vehicles.[2041]~~.~~ The flexibility proposed by Volkswagen would presumably be in addition to these~~is~~ existing ~~exemption~~provisions, but Volkswagen does not identify a source of authority for it. The agencies also have a number of questions about how specifically a SVLM concept might be implemented, such as whether every manufacturer would simply identify the 5,000 vehicles with the lowest projected VMT or lowest fuel economy and therefore qualify for credits for 5,000 vehicles every model year, or whether there should be additional criteria for vehicles to be included. The NPRM did not seek comment on a SVLM concept and the agencies did not receive other comments on the requested program. Therefore, the agencies are ~~denying the request~~ not adopting ~~for~~ the SVLM concept suggested by Volkswagen.

Commented [A455]: CHANGE AS SHOWN: To correct references to EPA's GHG program, and make clear that NHTSA is speaking to the CAFE program, not EPA.

E. CO_2 and CAFE Compliance Issues Not Addressed in the NPRM

1. CO_2 and CAFE Adjustments for 5-cycle Testing

EPA and NHTSA received several comments requesting that the agencies revise current CAFE test procedures to use EPA's 5-cycle test procedures in place of the 2-cycle test procedures that have been largely unchanged since the inception of the CAFE program, or offset measured 2-cycle test fuel economy and CO_2 emissions for CO_2 and CAFE compliance. Walter Kreucher commented "some technologies (Hybrid Electric) have penalties on the road that are not reflected on the tests used to determine CAFE compliance. ...If the Agencies want to provide adjustment factors for A/C and other 'Off-Cycle' conditions it must do so in both the positive and negative direction" (sic).[2042] AVE commented that the agencies should use 5-cycle procedures rather than 2-cycle procedures, arguing that the 5-cycle model better demonstrates real-world driving conditions and would lead to a more simplified credit allocation system.[2043] BorgWarner echoed those comments, stating that the 5-cycle test is more accurate than the 2-cycle test and would reduce the need for credit adjustments.[2044] Jeremy Michalek commented that the fuel economy values the public sees reflected on vehicles for purchase (e.g., on the Monroney label or in new car advertising) is calculated from the 5-cycle test; updating the 2-cycle test to capture more of the vehicle's fuel efficiency factors would allow for better consistency and a more accurate fuel efficiency measure.[2045] ~~The Auto Alliance proposed that the EPA revise its methodology for calculating off-cycle improvements when using the 5-cycle~~

[2040] 49 U.S.C. 32902(d)(1).
[2041] 40 CFR 86.1818-12(g).
[2042] Walter Kreucher, Detailed Comments, NHTSA-2018-0067-0444.
[2043] AVE, Detailed Comments, NHTSA-2018-0067-11696.
[2044] BorgWarner, Detailed Comments, NHTSA-2018-0067-11895.
[2045] Jeremy Michalek, et al., Detailed Comments, NHTSA-2018-0067-11903.

~~methodology by subtracting the 2-cycle benefit from the 5-cycle benefit to ensure credits are calculated properly.[2046]~~

The NPRM did not seek comment on revising compliance test procedures to use 5-cycle test procedures in place of 2-cycle test procedures, either entirely or broadly. Such a change would require extensive assessment and analysis to consider how changes could be implemented and what standards might be maximum feasible for CAFE and appropriate and reasonable for CO_2 for new test procedures. There has been no analysis conducted to estimate the impacts of such a change on the levels of the standards. ~~The agencies also did not propose to modify the off-cycle calculation for the 5-cycle measurement methodology as part of this rulemaking.~~ Therefore, making these requested changes is outside the scope of this rulemaking.

Commented [A456]: DELETE: This comment is out of place here, as it pertains to EPA's draft FRM technical amendment to correct the off-cycle 5-cycle pathway equation to back out the 2-cycle test result.

Commented [A457]: CHANGE AS SHOWN: Ditto above. This issue is addressed in EPA's draft FRM technical amendment on the off-cycle equation correction.

Commented [A458]: DELETE: Ditto above. This issue is addressed in EPA's draft FRM technical amendment on the off-cycle equation correction.

2. National Zero Emissions Vehicle Concept

Although the agencies did not discuss or request comment on a National Zero Emissions Vehicle (NZEV) program concept, several organizations commented on that topic. Some discussed ideas from a task force that was formed by the governors of nine States who signed a memorandum of understanding (MOU) committing to undertake joint cooperative actions to build a robust market for ZEVs under their individual state programs. Collectively, these States have committed to having at least 3.3 million ZEVs operating on their roadways by 2025. ZEVs include battery-electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), and hydrogen fuel-cell electric vehicles (FCEVs). Comments on an NZEV concept were received from General Motors, CARB, Edison Electric Institute, Honda, NCAT, Workhorse Group, and Volvo.

General Motors offered comments supporting an NZEV program, stating that it continues to expect California to be the leader of the EV market but hopes a national effort will be put forth, making the U.S. a global leader in EV technology development and deployment.[2047] General Motors stated it believes an NZEV program would further U.S. national security interests, make the U.S. more competitive with China, which already has an NZEV program, and reduce U.S. dependence on foreign petroleum. General Motors requested that EPA incentivize EV deployment, including providing credits for autonomous EVs and EVs that are used in rideshare programs.[2048] General Motors outlined their proposed NZEV program which would include increasing ZEV requirements annually, establishing credit banks for manufacturers based on national ZEV sales, and ZEV multipliers for vehicles over 5,250 lbs., autonomous vehicles using EV, and EVs in rideshare programs. General Motors also proposed that requirements would be revisited if EV battery cell were not available at the costs Argonne National Lab forecasts by 2025. General Motors also suggested implementing a Zero Emissions Task Force that would promote complementary policies. General Motors acknowledged that the NZEV program would have to be subject to acceleration or delay depending on how quickly technologies are incentivized like battery cost.

~~[2046] Auto Alliance, Detailed Comments, NHTSA-2018-0067-12073.~~

[2047] General Motors, Detailed Comments, NHTSA-2018-0067-11858.

[2048] General Motors, Detailed Comments, NHTSA-2018-0067-11858.

CARB recommended a national ZEV multiplier, stating that a national incentive would help ensure ZEVs and PHEVs were being produced for sale beyond the ten States that have ZEV programs.[2049] The Edison Electric Institute supported increasing stringency of fuel economy and CO_2 standards and incorporating policies from ZEV States to create a "One National Program."[2050] Workhorse Group commented that a national ZEV mandate, where agencies progressively increase the mandated percentage of electric vehicles in every fleet, merits serious consideration by the agencies. They contended that an NZEV would have to work with the current State ZEV mandates and not preempt the progress already made.[2051] Volvo, and Honda were proponents of incorporating ZEV standards into a national program. Volvo requested nationwide credits for ZEVs since there are 40 States without ZEV mandates.[2052] Honda mentioned that incorporating California's ZEV credits into the national program would reduce compliance costs for manufacturers while incentivizing technological development.[2053] NCAT recommended in their comment that EPA provide enhanced credits for EVs, PHEVs, and FCVs that are more stringent than California (and other States) ZEV mandates, making the national program credits "additional" to state ZEV compliance credits.[2054]

Northeast States for Coordinated Air Use Management (NESCAUM) commented that an aggressive reduction in emissions will not occur without national ZEV standards which will drive development of advanced clean vehicle technologies.[2055]

The NPRM did not propose or request comment on an NZEV concept or program, as such, and establishing such a program would be outside the scope of this rulemaking. Such a concept would require thorough assessment and full rulemaking notice and comment. There are also policy questions about what the appropriate level of potential incentives should be and whether certain technologies should receive greater incentives than other technologies, and if so, on what basis and by what amounts. Also, for the CAFE program, incentives for technologies are almost entirely prescribed by statute, and there are questions about how the CAFE program could implement an NZEV program in alignment with EPCA and EISA. Therefore, the agencies have decided not to implement an NZEV program as part of this rulemaking.

F. Medium- and Heavy-Duty Fuel Efficiency Technical Amendments

NHTSA proposed in the NPRM to make minor technical revisions to correct typographical mistakes and improper references adopted in the agency's 2016 Phase 2 medium- and heavy-duty fuel efficiency rule.[2056] The proposed changes were as follows:

- NHTSA heavy-duty vehicles and engine fuel consumption credit equations. In each credit equation in 49 CFR 535.7, the minus-sign in each multiplication factor was

[2049] CARB, Detailed Comments, NHTSA-2018-0067-11873.
[2050] Edison Electric Institute, Detailed Comments, NHTSA-2018-0067-11918.
[2051] Workhorse Group, Detailed Comments, NHTSA-2018-0067-12215.
[2052] Volvo, Detailed Comments, NHTSA-2018-0067-12036.
[2053] Honda, Detailed Comments, NHTSA-2018-0067-11818.
[2054] NCAT, Detailed Comments, NHTSA-2018-0067-11969.
[2055] NESCAUM, Detailed Comments, NHTSA-2018-0067-11691.
[2056] 81 FR 73478 (Oct. 25, 2016).

omitted in the final version of the rule sent to the *Federal Register*. For example, the credit equation in Part 535.7(b)(1) should be specified as, Total MY Fleet FCC (gallons) = (Std - Act) × (Volume) × (UL) × (10-2) instead of (102), as currently exists. NHTSA proposed to correct these omissions.

- The CO_2 to gasoline conversion factor: In 49 CFR 535.6(a)(4)(ii) and (d)(5)(ii), NHTSA provides the methodology and equations for converting the CO_2 FELs/FCLs for heavy-duty pickups and vans (gram per mile) and for engines (grams per hp-hr) to their gallon-of-gasoline equivalence. In each equation, NHTSA proposed to correct the conversion factor to 8,887 grams per gallon of gasoline fuel instead of a factor of 8,877 as currently specified.
- Curb weight definition: In 49 CFR 523.2, the reference in the definition for curb weight is incorrect. NHTSA proposed to correct the definition to incorporate a reference to 40 CFR 86.1803 instead of 49 CFR 571.3.

No public comments were received in response to NHTSA's proposed technical corrections. Therefore, NHTSA is finalizing these amendments and incorporating them into its heavy-duty regulations.

X. Regulatory Notices and Analyses

A. Executive Order 12866, Executive Order 13563

Executive Order 12866, "Regulatory Planning and Review" (58 FR 51735, Oct. 4, 1993), as amended by Executive Order 13563, "Improving Regulation and Regulatory Review" (76 FR 3821, Jan. 21, 2011), provides for making determinations whether a regulatory action is "significant" and therefore subject to the Office of Management and Budget (OMB) review and to the requirements of the Executive Order. One comment requested that the agencies provide "a far more robust cost/benefit analysis as required by Executive Order (EO) 12866 and Office of Management and Budget Circular A-4."[2057] The NPRM and this final rule satisfy the requirements of Executive Order 12866, "Regulatory Planning and Review" (58 FR 51735, Oct. 4, 1993), as amended by Executive Order 13563, "Improving Regulation and Regulatory Review" (76 FR 3821, Jan. 21, 2011). Under these Executive Orders, this action is an "economically significant regulatory action" because it is likely to have an annual effect on the economy of $100 million or more. Accordingly, EPA and NHTSA submitted this action to the OMB for review and any changes made in response to OMB recommendations have been documented in the docket for this action. The benefits and costs of this proposal are described

[2057] *See* Anonymous Comment, Docket No. EPA-HQ-OAR-2018-0283-3896, at 4-5 (footnote and citation omitted). As an example, the comment critiqued the NPRM's discussion of the "diminishing returns" of fuel economy benefits, alleging that the discussion "is not backed by reference to data or studies regarding how this conclusion was made." *Id.* at 5. Contrary to the comment's allegation, the conclusion is supported by the analysis from U.S. Energy Information Administration's (EIA's) Annual Energy Outlook (AEO) that was cited in the discussion. *Id.* As noted in the NPRM, the EIA—the statistical and analytical agency within the U.S. Department of Energy (DOE)—is the nation's premier source of energy information, and every fuel economy rulemaking since 2002 (and every joint CAFE and CO_2 rulemaking since 2009) has applied fuel price projections from EIA's AEO. *Id.* at 42992 n.24.

above and in the Final Regulatory Impact Analysis (FRIA), which is located in the docket and on the agencies' websites.

B. DOT Regulatory Policies and Procedures

The rule is also significant within the meaning of the Department of Transportation's Regulatory Policies and Procedures. The benefits and costs of this proposal are described above and in the FRIA, which is located in the docket and on NHTSA's website.

C. Executive Order 13771 (Reducing Regulation and Controlling Regulatory Costs)

This rule is an E.O. 13771 deregulatory action. Per OMB Memorandum M-17-21, because this rule is deregulatory, it is not required to be offset by two deregulatory actions, as one comment suggested.[2058] Details on the estimated cost savings of this proposed rule can be found in FRIA, which is located in the docket and on the agencies' websites.

D. Executive Order 13211 (Energy Effects)

Executive Order 13211 applies to any rule that: (1) is determined to be economically significant as defined under E.O. 12866, and is likely to have a significant adverse effect on the supply, distribution, or use of energy; or (2) that is designated by the Administrator of the Office of Information and Regulatory Affairs as a significant energy action. If the regulatory action meets either criterion, the agencies must evaluate the adverse energy effects of the rule and explain why the regulation is preferable to other potentially effective and reasonably feasible alternatives considered.

The rule establishes passenger car and light truck fuel economy standards and tailpipe carbon dioxide and related emissions standards. An evaluation of energy effects of the action and reasonably feasible alternatives considered is provided in NHTSA's EIS and in the FRIA. To the extent that EPA's CO_2 standards are substantially related to fuel economy and, accordingly, petroleum consumption, the EIS and FRIA analyses also provide an estimate of impacts of EPA's rule.

E. Environmental Considerations

1. National Environmental Policy Act (NEPA)

Concurrently with this final rule, NHTSA is releasing a Final Environmental Impact Statement (Final EIS), pursuant to the National Environmental Policy Act, 42 U.S.C. 4321-4347, and implementing regulations issued by the Council on Environmental Quality (CEQ), 40 CFR part 1500, and NHTSA, 49 CFR part 520. This preamble and final rule serve as the Record of Decision under 23 CFR 1505.2. NHTSA has authority to issue its Final EIS and Record of Decision simultaneously pursuant to 49 U.S.C. 304a(b) and U.S. Department of Transportation, Office of Transportation Policy, *Guidance on the Use of Combined Final Environmental Impact*

[2058] Anonymous Comment, Docket No. EPA-HQ-OAR-2018-0283-3896, at 8.

Statements/Records of Decision and Errata Sheets in National Environmental Policy Act Reviews (April 25, 2019).[2059] NHTSA has determined that neither the statutory criteria nor practicability considerations preclude simultaneous issuance.

NHTSA prepared the Final EIS to analyze and disclose the potential environmental impacts of the proposed CAFE standards and a range of alternatives. The Final EIS analyzes direct, indirect, and cumulative impacts and analyzes impacts in proportion to their significance. It describes potential environmental impacts to a variety of resources, including fuel and energy use, air quality, climate, land use and development, hazardous materials and regulated wastes, historical and cultural resources, noise, and environmental justice. The Final EIS also describes how climate change resulting from global carbon emissions (including CO_2 emissions attributable to the U.S. light duty transportation sector under the alternatives considered) could affect certain key natural and human resources. Resource areas are assessed qualitatively and quantitatively, as appropriate, in the Final EIS.

NHTSA also performed a national-scale photochemical air quality modeling and health benefit assessment for the Final EIS; it is included as Appendix E. The purpose of this assessment was to use air quality modeling and health-related benefits analysis tools to examine the potential air quality-related consequences of the alternatives considered in its Draft EIS. In a comment on the Draft EIS, the South Coast Air Quality Management District stated that performing the photochemical modeling for the Final EIS "comes too late for the public to be able to comment on that analysis," and that the EIS must be recirculated to allow such public comment.[2060] However, NHTSA publicly stated its intent to conduct the analysis as part of the Final EIS in its scoping notice published on July 26, 2017.[2061] The agency noted that this approach was consistent with past practice and resulted from the substantial time required to complete such an analysis. NHTSA also announced that, due to the substantial lead time required, the analysis would be based on the modeling of the alternatives presented in the Draft EIS, not of the alternatives as presented in the Final EIS. NHTSA received no public comments in response to the scoping notice addressing this analytical approach, and the agency proceeded accordingly. Furthermore, while photochemical modeling provides spatial and temporal detail for estimating changes in ambient levels of air pollutants and their associated impacts on human health and welfare, the analysis affirms the estimates that appear in the EIS and does not provide significant new information for the decisionmaker or the public. For these reasons, NHTSA concludes that inclusion of the photochemical modeling and health benefit assessment in the Final EIS is appropriate, and recirculation of the EIS is not required.

NHTSA has considered the information contained in the Final EIS in making the final decision described in this final rule. Specifically, NHTSA addresses the findings of the Final

[2059] The guidance is available at https://www.transportation.gov/sites/dot.gov/files/docs/mission/transportation-policy/permittingcenter/337371/feis-rod-guidance-final-04302019.pdf.
[2060] South Coast Air Quality Management District, Docket No. NHTSA-2018-0067-5666, at 10.
[2061] NHTSA, "Notice of Intent to Prepare an Environmental Impact Statement for Model Year 2022–2025 Corporate Average Fuel Economy Standards," 82 FR 34740, 34743 fn. 15 (Jul. 26, 2017).

EIS in Section 8 of this preamble. The Final EIS is available for review in the public docket for this action and in Docket No. NHTSA-2017-0069.

The North Carolina Department of Environmental Quality commented that the proposed changes to the CAFE standards could undermine the integrity of many of the assumptions in various NEPA documents across the United States, in part because EPA required the use of the MOVES2014 model (or a subsequent revision) for transportation conformity determinations.[2062] That version of MOVES incorporates CAFE and CO_2 standards based on the agencies' actions in 2012 and does not reflect the actions being finalized in this rule. The implication of the commenter's assertion, however, is that neither NHTSA nor EPA could take any regulatory action regarding CAFE or CO_2 standards, regardless of whether such action were to increase or decrease such standards. Clearly neither agency can be paralyzed from undertaking its statutory obligations because of the independent NEPA obligations related to other ongoing Federal actions. For those actions, responsible officials may need to assess whether this final rule triggers the need for a supplemental NEPA document. However, it is not unique for Federal agencies to take actions or for new information to become available that affects the underlying inputs in models, such as EPA's MOVES model, on which NEPA and conformity analyses rely. Over time, those models will be updated to reflect these actions and information. EPA is responsible for approving the availability of models for the use in State implementation plans and transportation conformity analyses. Conformity analyses can continue to rely on the latest models approved by EPA until more current models are developed and approved. Furthermore, the agencies anticipate that guidance on the application of current models will be forthcoming.

[Text Forthcoming]

2. Clean Air Act (CAA) as Applied to NHTSA's Action

The CAA (42 U.S.C. 7401 et seq.) is the primary Federal legislation that addresses air quality. Under the authority of the CAA and subsequent amendments, EPA has established National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, which are specifically identified pollutants that have recognized adverse effects on ambient air quality and that can accumulate in the atmosphere as a result of human activity. EPA is required to review each NAAQS every five years and to revise those standards as may be appropriate considering new scientific information.

The air quality of a geographic region is usually assessed by comparing the levels of criteria air pollutants found in the ambient air to the levels established by the NAAQS (taking into account, as well, the other elements of a NAAQS: averaging time, form, and indicator). Concentrations of criteria pollutants within the air mass of a region are measured in parts of a pollutant per million parts (ppm) of air or in micrograms of a pollutant per cubic meter ($\mu g/m^3$) of air present in repeated air samples taken at designated monitoring locations using specified types of monitors. These ambient concentrations of each criteria pollutant are compared to the

[2062] North Carolina Department of Environmental Quality, Docket No. NHTSA-2018-0067-12025, at 37.

levels, averaging time, and form specified by the NAAQS in order to assess whether the region's air quality is in attainment with the NAAQS.

When the measured concentrations of a criteria pollutant within a geographic region are below those permitted by the NAAQS, EPA designates the region as an attainment area for that pollutant, while regions where concentrations of criteria pollutants exceed Federal standards are called nonattainment areas. Former nonattainment areas that are now in compliance with the NAAQS are designated as maintenance areas. Each State with a nonattainment area is required to develop and implement a State Implementation Plan (SIP) documenting how the region will reach attainment levels within time periods specified in the CAA. For maintenance areas, the SIP must document how the State intends to maintain compliance with the NAAQS. When EPA revises a NAAQS, each State must revise its SIP to address how it plans to attain the new standard.

No Federal agency may "engage in, support in any way or provide financial assistance for, license or permit, or approve" any activity that does not "conform" to a SIP or Federal Implementation Plan after EPA has approved or promulgated it.[2063] Further, no Federal agency may "approve, accept, or fund" any transportation plan, program, or project developed pursuant to title 23 or chapter 53 of title 49, U.S.C., unless the plan, program, or project has been found to "conform" to any applicable implementation plan in effect.[2064] The purpose of these conformity requirements is to ensure that Federally sponsored or conducted activities do not interfere with meeting the emissions targets in SIPs, do not cause or contribute to new violations of the NAAQS, and do not impede the ability of a State to attain or maintain the NAAQS or delay any interim milestones. EPA has issued two sets of regulations to implement the conformity requirements:

(1) The Transportation Conformity Rule[2065] applies to transportation plans, programs, and projects that are developed, funded, or approved under title 23 or chapter 53 of title 49, U.S.C.

(2) The General Conformity Rule[2066] applies to all other federal actions not covered under transportation conformity. The General Conformity Rule establishes emissions thresholds, or *de minimis* levels, for use in evaluating the conformity of an action that results in emissions increases.[2067] If the net increases of direct and indirect emissions are lower than these thresholds, then the project is presumed to conform and no further conformity evaluation is required. If the net increases of direct and indirect emissions exceed any of these thresholds, and the action is not otherwise exempt, then a conformity determination is required. The conformity determination can entail air quality modeling studies, consultation with EPA and state air quality agencies, and commitments to revise the SIP or to implement measures to mitigate air quality impacts.

The CAFE standards and associated program activities are not developed, funded, or approved under title 23 or chapter 53 of title 49, United States Code. Accordingly, this action

[2063] 42 U.S.C. 7506(c)(1).
[2064] 42 U.S.C. 7506(c)(2).
[2065] 40 CFR part 51, subpart T, and part 93, subpart A.
[2066] 40 CFR part 51, subpart W, and part 93, subpart B.
[2067] 40 CFR 93.153(b).

and associated program activities are not subject to the Transportation Conformity Rule. Under the General Conformity Rule, a conformity determination is required where a Federal action would result in total direct and indirect emissions of a criteria pollutant or precursor originating in nonattainment or maintenance areas equaling or exceeding the rates specified in 40 CFR 93.153(b)(1) and (2). As explained below, NHTSA's proposed action results in neither direct nor indirect emissions as defined in 40 CFR 93.152.

The General Conformity Rule defines direct emissions as "those emissions of a criteria pollutant or its precursors that are caused or initiated by the Federal action and originate in a nonattainment or maintenance area and occur at the same time and place as the action and are reasonably foreseeable."[2068] Because NHTSA's action would set fuel economy standards for light duty vehicles, it would cause no direct emissions consistent with the meaning of the General Conformity Rule.[2069]

Indirect emissions under the General Conformity Rule are "those emissions of a criteria pollutant or its precursors (1) that are caused or initiated by the federal action and originate in the same nonattainment or maintenance area but occur at a different time or place as the action; (2) that are reasonably foreseeable; (3) that the agency can practically control; and (4) for which the agency has continuing program responsibility."[2070] Each element of the definition must be met to qualify as indirect emissions. NHTSA has determined that, for purposes of general conformity, emissions that may result from the proposed fuel economy standards would not be caused by NHTSA's action, but rather would occur because of subsequent activities the agency cannot practically control. "[E]ven if a Federal licensing, rulemaking, or other approving action is a required initial step for a subsequent activity that causes emissions, such initial steps do not mean that a Federal agency can practically control any resulting emissions."[2071]

As the CAFE program uses performance-based standards, NHTSA cannot control the technologies vehicle manufacturers use to improve the fuel economy of passenger cars and light trucks. Furthermore, NHTSA cannot control consumer purchasing (which affects average achieved fleetwide fuel economy) and driving behavior (i.e., operation of motor vehicles, as measured by VMT). It is the combination of fuel economy technologies, consumer purchasing, and driving behavior that results in criteria pollutant or precursor emissions. For purposes of analyzing the environmental impacts of the alternatives considered here and under NEPA, NHTSA has made assumptions regarding all of these factors. The agency's Final EIS predicts that increases in air toxic and criteria pollutants would occur in some nonattainment areas under certain alternatives. However, the standards and alternatives do not mandate specific

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[2068] 40 CFR 93.152.
[2069] Dep't of Transp. v. Pub. Citizen, 541 U.S. 752, 772 (2004) ("[T]he emissions from the Mexican trucks are not 'direct' because they will not occur at the same time or at the same place as the promulgation of the regulations."). NHTSA's action is to establish fuel economy standards for MY 2021–2026 passenger car and light trucks; any emissions increases would occur in a different place and well after promulgation of the final rule.
[2070] 40 CFR 93.152.
[2071] 40 CFR 93.152.

manufacturer decisions, consumer purchasing, or driver behavior, and NHTSA cannot practically control any of them.[2072]

In addition, NHTSA does not have the statutory authority to control the actual VMT by drivers. As the extent of emissions is directly dependent on the operation of motor vehicles, changes in any emissions that result from NHTSA's CAFE standards are not changes the agency can practically control or for which the agency has continuing program responsibility. Therefore, the final CAFE standards and alternative standards considered by NHTSA would not cause indirect emissions under the General Conformity Rule, and a general conformity determination is not required.

[Text Forthcoming]

3. National Historic Preservation Act (NHPA)

The NHPA (54 U.S.C. 300101 *et seq.*) sets forth government policy and procedures regarding "historic properties"—that is, districts, sites, buildings, structures, and objects included on or eligible for the National Register of Historic Places. Section 106 of the NHPA requires Federal agencies to "take into account" the effects of their actions on historic properties.[2073] In the NPRM, the agencies concluded that the NHPA is not applicable to this rulemaking because the promulgation of CAFE and CO_2 emissions standards for light duty vehicles is not the type of activity that has the potential to cause effects on historic properties.

One commenter wrote that "[c]limate change and air pollution imperil historic properties throughout the country via direct degradation, sea level rise, fire, flood, and other forms of harm." Therefore, the commenter concluded that NHTSA and EPA must consult with the relevant Federal and State authorities and fully disclose any impacts to historic properties.[2074] However, as this final rule establishes CAFE and CO_2 standards that increase each year for MYs 2021–2026, this action will result in reductions in climate change-related impacts and most air pollutants compared to the absence of regulation. Furthermore, any impacts to particular historic properties that could be related to emissions changes associated with this rulemaking are not reasonably certain to occur, would be *de minimis* in their level of impact if they did occur, and are too attenuated to be attributed directly to this action. There is no evidence that the changes in air pollution or CO_2 emissions associated with this rulemaking, in and of themselves, would alter the characteristics of a historic property qualifying it for inclusion in or eligibility for the National Register.[2075] Nevertheless, NHTSA includes a brief, qualitative discussion of the impacts of the alternatives on historical and cultural resources in Section 7.3 of the Final EIS. For the foregoing reasons, the agencies continue to conclude that any potential impacts have

Commented [A459]: REVISE: This is not correct for the EPA GHG program because "the absence of regulation" (in this case, the SAFE FRM) would be the existing EPA standards which are more stringent than those finalized in this action. This action revising the GHG standards will result in increased climate impacts and air pollution emissions compared to the existing standards.

[2072] *See*, e.g., Dep't of Transp. v. Pub. Citizen, 541 U.S. 752, 772-73 (2004); S. Coast Air Quality Mgmt. Dist. v. Fed. Energy Regulatory Comm'n, 621 F.3d 1085, 1101 (9th Cir. 2010).
[2073] Section 106 is now codified at 54 U.S.C. 306108. Implementing regulations for the Section 106 process are located at 36 CFR part 800.
[2074] CARB, Docket No. NHTSA-2018-0067-11873, at 411.
[2075] 36 CFR 800.16(i).

been accounted for in the associated analyses of this rulemaking and that no consultation is required under the NHPA.

[Text Forthcoming]

4. Fish and Wildlife Conservation Act (FWCA)

The FWCA (16 U.S.C. 2901 *et seq.*) provides financial and technical assistance to States for the development, revision, and implementation of conservation plans and programs for nongame fish and wildlife. In addition, the Act encourages all Federal departments and agencies to utilize their statutory and administrative authorities to conserve and to promote conservation of nongame fish and wildlife and their habitats. The agencies conclude that the FWCA is not applicable to this final rule because this rulemaking does not involve the conservation of nongame fish and wildlife and their habitats. NHTSA has, however, conducted a qualitative review in its Final EIS of the related direct, indirect, and cumulative impacts, positive or negative, of the alternatives on potentially affected resources, including nongame fish and wildlife and their habitats.

5. Coastal Zone Management Act (CZMA)

The Coastal Zone Management Act (16 U.S.C. 1451 *et seq.*) provides for the preservation, protection, development, and (where possible) restoration and enhancement of the Nation's coastal zone resources. Under the statute, States are provided with funds and technical assistance in developing coastal zone management programs. Each participating State must submit its program to the Secretary of Commerce for approval. Once the program has been approved, any activity of a Federal agency, either within or outside of the coastal zone, that affects any land or water use or natural resource of the coastal zone must be carried out in a manner that is consistent, to the maximum extent practicable, with the enforceable policies of the State's program.[2076]

In the NPRM, the agencies concluded that the CZMA is not applicable to this rulemaking because this rulemaking does not involve an activity within, or outside of, the Nation's coastal zones that affects any land or water use or natural resource of the coastal zone. CARB commented that California's coast is vulnerable to sea level rise from climate change and that the proposal would exacerbate that threat. Therefore, the commenter claimed that the proposal violated California's policies and obligations in its management program to preserve, protect, and enhance its coastline.[2077] However, in its Final EIS, NHTSA estimates that the sea-level rise in 2100 associated with Alternative 1 (0 percent annual average increase for both passenger cars and light trucks for MYs 2021–2026), the least stringent alternative considered, would be 0.7 mm. Such a level is too small to have any meaningful impact on land or water use or a natural resource of the coastal zone. Furthermore, as this final rule establishes CAFE and CO_2 standards that increase each year for MYs 2021–2026, this action will result in reductions in sea level rise resulting from climate change compared to the absence of regulation. Therefore, the

[2076] 16 U.S.C. 1456(c)(1)(A).
[2077] CARB, Docket No. NHTSA-2018-0067-11873, at 411.

agencies continue to conclude that the CZMA is not applicable to this rulemaking. NHTSA has, however, conducted a qualitative review in its Final EIS of the related direct, indirect, and cumulative impacts, positive or negative, of the alternatives on potentially affected resources, including coastal zones.

6. Endangered Species Act (ESA)

Under Section 7(a)(2) of the ESA, Federal agencies must ensure that actions they authorize, fund, or carry out are "not likely to jeopardize the continued existence" of any Federally listed threatened or endangered species or result in the destruction or adverse modification of the designated critical habitat of these species. 16 U.S.C. 1536(a)(2). If a Federal agency determines that an agency action may affect a listed species or designated critical habitat, it must initiate consultation with the appropriate Service—the U.S. Fish and Wildlife Service of the Department of the Interior and/or the National Oceanic and Atmospheric Administration's National Marine Fisheries Service of the Department of Commerce, depending on the species involved—in order to ensure that the action is not likely to jeopardize the species or destroy or adversely modify designated critical habitat. *See* 50 CFR 402.14. Under this standard, the Federal agency taking action evaluates the possible effects of its action and determines whether to initiate consultation. *See* 51 Fed. Reg. 19926, 19949 (June 3, 1986).

Pursuant to Section 7(a)(2) of the ESA, the agencies have considered the effects of the standards and have reviewed applicable ESA regulations, case law, and guidance to determine what, if any, impact there might be to listed species or designated critical habitat. The agencies have considered issues related to emissions of CO_2 and other pollutants. Based on this assessment, the agencies have determined that the actions of setting CAFE and CO_2 emissions standards does not require consultation under Section 7(a)(2) of the ESA. Accordingly, NHTSA and EPA have concluded its review of this action under Section 7 of the ESA.

[Text Forthcoming]

7. Floodplain Management (Executive Order 11988 and DOT Order 5650.2)

These Orders require Federal agencies to avoid the long- and short-term adverse impacts associated with the occupancy and modification of floodplains, and to restore and preserve the natural and beneficial values served by floodplains. Executive Order 11988 also directs agencies to minimize the impact of floods on human safety, health, and welfare, and to restore and preserve the natural and beneficial values served by floodplains through evaluating the potential effects of any actions the agency may take in a floodplain and ensuring that its program planning and budget requests reflect consideration of flood hazards and floodplain management. DOT Order 5650.2 sets forth DOT policies and procedures for implementing Executive Order 11988. The DOT Order requires that the agency determine if a proposed action is within the limits of a base floodplain, meaning it is encroaching on the floodplain, and whether this encroachment is significant. If significant, the agency is required to conduct further analysis of the proposed action and any practicable alternatives. If a practicable alternative avoids floodplain encroachment, then the agency is required to implement it.

In this rulemaking, the agencies are not occupying, modifying and/or encroaching on floodplains. The agencies, therefore, conclude that the Orders are not applicable to this action. NHTSA has, however, conducted a review of the alternatives on potentially affected resources, including floodplains, in its Final EIS.

8. Preservation of the Nation's Wetlands (Executive Order 11990 and DOT Order 5660.1a)

These Orders require Federal agencies to avoid, to the extent possible, undertaking or providing assistance for new construction located in wetlands unless the agency head finds that there is no practicable alternative to such construction and that the proposed action includes all practicable measures to minimize harm to wetlands that may result from such use. Executive Order 11990 also directs agencies to take action to minimize the destruction, loss, or degradation of wetlands in "conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities." DOT Order 5660.1a sets forth DOT policy for interpreting Executive Order 11990 and requires that transportation projects "located in or having an impact on wetlands" should be conducted to assure protection of the Nation's wetlands. If a project does have a significant impact on wetlands, an EIS must be prepared.

The agencies are not undertaking or providing assistance for new construction located in wetlands. The agencies, therefore, conclude that these Orders do not apply to this rulemaking. NHTSA has, however, conducted a review of the alternatives on potentially affected resources, including wetlands, in its Final EIS.

9. Migratory Bird Treaty Act (MBTA), Bald and Golden Eagle Protection Act (BGEPA), Executive Order 13186

The MBTA (16 U.S.C. 703–712) provides for the protection of certain migratory birds by making it illegal for anyone to "pursue, hunt, take, capture, kill, attempt to take, capture, or kill, possess, offer for sale, sell, offer to barter, barter, offer to purchase, purchase, deliver for shipment, ship, export, import, cause to be shipped, exported, or imported, deliver for transportation, transport or cause to be transported, carry or cause to be carried, or receive for shipment, transportation, carriage, or export" any migratory bird covered under the statute.[2078]

The BGEPA (16 U.S.C. 668-668d) makes it illegal to "take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import" any bald or golden eagles.[2079] Executive Order 13186, "Responsibilities of Federal Agencies to Protect Migratory Birds," helps to further the purposes of the MBTA by requiring a Federal agency to develop a Memorandum of Understanding (MOU) with the Fish and Wildlife Service when it is taking an action that has (or is likely to have) a measurable negative impact on migratory bird populations.

[2078] 16 U.S.C. 703(a).
[2079] 16 U.S.C. 668(a).

The agencies conclude that the MBTA, BGEPA, and Executive Order 13186 do not apply to this action because there is no disturbance, take, measurable negative impact, or other covered activity involving migratory birds or bald or golden eagles involved in this rulemaking.

10. Department of Transportation Act (Section 4(f))

Section 4(f) of the Department of Transportation Act of 1966 (49 U.S.C. 303), as amended, is designed to preserve publicly owned park and recreation lands, waterfowl and wildlife refuges, and historic sites. Specifically, Section 4(f) provides that DOT agencies cannot approve a transportation program or project that requires the use of any publicly owned land from a public park, recreation area, or wildlife or waterfowl refuge of national, State, or local significance, or any land from a historic site of national, State, or local significance, unless a determination is made that:

(1) There is no feasible and prudent alternative to the use of land, and

(2) The program or project includes all possible planning to minimize harm to the property resulting from the use.

These requirements may be satisfied if the transportation use of a Section 4(f) property results in a de minimis impact on the area.

NHTSA concludes that Section 4(f) is not applicable to this action because this rulemaking is not an approval of a transportation program or project that requires the use of any publicly owned land.

11. Executive Order 12898: "Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations"

Executive Order 12898 (59 FR 7629 (Feb. 16, 1994)) establishes Federal executive policy on environmental justice. Its main provision directs Federal agencies, to the greatest extent practicable and permitted by law, to make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on minority populations and low-income populations in the United States. DOT Order 5610.2(a)[2080] sets forth the Department's policy to consider environmental justice principles in all its programs, policies, and activities.

Environmental justice is a principle asserting that all people deserve fair treatment and meaningful involvement with respect to environmental laws, regulations, and policies. EPA seeks to provide the same degree of protection from environmental health hazards for all people. DOT shares this goal and is informed about the potential environmental impacts of its rulemakings through the NEPA process. One comment on the NPRM claimed that the agencies "failed to recognize the benefits of the existing standards" for disadvantaged communities. Specifically, the commenter claimed that the agencies did not provide an underlying analysis of

[2080] Department of Transportation Updated Environmental Justice Order 5610.2(a), 77 FR 27534 (May 10, 2012).

environmental justice issues and thereby failed to meet the requirements of EO 12898.[2081] However, the agencies addressed their obligations under EO 12898 in the preamble to the NPRM and in Section 7.5 of the DEIS. The agencies have revised the analysis based on other comments received and present it again here and in the FEIS. [Text Forthcoming]

Numerous studies have found that some environmental hazards are more prevalent in areas where racial/ethnic minorities and people with low socioeconomic status (SES) represent a higher proportion of the population compared with the general population. In addition, compared to non-Hispanic whites, some subpopulations defined by race and ethnicity have been shown to have a greater incidence of some health conditions during certain life stages. For example, in 2014, about 13 percent of Black, non-Hispanic and 24 percent of Puerto Rican children were estimated to have asthma, compared with 8 percent of white, non-Hispanic children.[2082] The agencies have therefore considered areas nationwide that could contain minority and low-income communities who would most likely be exposed to the environmental and health impacts of oil production, distribution, and consumption or the potential impacts of climate change. These include areas where oil production and refining occur, areas near roadways, coastal flood-prone areas, and urban areas that are subject to the heat island effect.[2083]

The following discussion addresses environmental justice implications related to air quality aud to climate change and carbon emissions in the context of this final rulemaking. NHTSA also discusses environmental justice in Chapter 7.5 of its FEIS.

a) Air Quality

The agencies have identified two locations of focus regarding air quality emissions and environmental justice: areas in proximity to oil production and refining and areas in proximity to high traffic roadways. Emissions in these areas may be affected by this rulemaking due to changes in fuel use and VMT, which are described above. To the degree to which minority and low-income populations may be present in proximity to these locations, they may be exposed disproportionately to these emissions changes. In addition, this section also discusses other potential reasons why minority and low-income populations may be susceptible to the health impacts of air pollutants.

[2081] CARB, Docket No. NHTSA-2018-0067-11873, at 411-12.
[2082] http://www.cdc.gov/asthma/most_recent_data.htm.
[2083] The heat island effect refers to developed areas having higher temperatures than surrounding rural areas.

(1) Proximity to Oil Production and Refining

There is evidence that proximity to oil refineries could be correlated with incidences of cancer and leukemia.[2084, 2085, 2086]

Studies have found mixed evidence regarding a nationwide correlation between proximity to oil refineries and the prevalence of minority and low-income populations. One report shows that at a nationwide level, roughly 5.1 million of 9 million people living near hazardous waste facilities are minorities, but does not specify how many of these minorities are living close to refineries in particular.[2087] Rather, the report highlights several case studies of minority populations affected by pollution from oil refineries, suggesting that these cases are likely to be indicative of overall national trends. Similarly, another report provides case study data from Richmond, California, showing that minority and low-income populations in this region live close to five major oil refineries.[2088]

At the national level, one study found that "56 percent of people living within 3 miles of refineries in the United States are minorities," which is almost double the national average.[2089] A separate report found that 91 counties across America either have or are building refineries close to more than 6.7 million African Americans, which amounts to 14 percent of the national average.[2090] In terms of the oil refining process as a whole, according to one study, the minority

[2084] Pukkala, E. *Cancer incidence among Finnish oil refinery workers*, 1971–1994. Journal of Occupational and Environmental Medicine. 40(8):675–679 (1998). doi:10.1023/A:1018474919807.

[2085] Chan, C.-C.; Shie, R.H.; Chang, T.Y.; Tsai, D.H. *Workers' exposures and potential health risks to air toxics in a petrochemical complex assessed by improved methodology*. International Archives of Occupational and Environmental Health. 79(2):135–142 (2006). doi:10.1007/s00420-005-0028-9 [Online at: https://www.researchgate.net/publication/7605242_Workers'_exposures_and_potential_health_risks_to_air_toxics_in_a_petrochemical_complex_assessed_by_improved_methodology].

[2086] Butka, C.; Nastoupil, L.J.; McClellan, W.; Ambinder, A.; Phillips, A.; Ward, K.; Bayakly, A.R.; Switchenko, J.M.; Waller, L.; Flowers, C.R. *Residence proximity to benzene release sites is associated with increased incidence of non-Hodgkin lymphoma. Cancer*. 119(18):3309–3317 (2013). doi:10.1002/cncr.28083. [Online at: http://onlinelibrary.wiley.com/doi/10.1002/cncr.28083/pdf;jsessionid=1520A90A764A95985316057D7D76A362.f02t02].

[2087] UCC (United Church of Christ). *Toxic Wastes and Race at Twenty*: 1987 – 2007. A Report Prepared for the United Church of Christ Justice and Witness Ministries. Available at: https://www.nrdc.org/sites/default/files/toxic-wastes-and-race-at-twenty-1987-2007.pdf (2007). (Accessed: April 9, 2018).

[2088] Kay, J. and C. Katz. Pollution, Poverty and People of Color: Living With Industry. Scientific American. Available at: https://www.scientificamerican.com/article/pollution-poverty-people-color-living-industry/ (2012). (Accessed: March 4, 2018).

[2089] O'Rourke, D. and S. Connolly. *Just Oil? The Distribution of Environmental and Social Impacts of Oil Production and Consumption*. Annual Review of Environment and Resources 28(1):587–617 (2003). doi:10.1146/annurev.energy.28.050302.105617.

[2090] National Association for the Advancement of Colored People and Clean Air Task Force. *Fumes Across the Fence-line: The Health Impacts of Air Pollution from Oil & Gas Facilities on African American Communities* (2017). Available at: http://www.catf.us/wp-content/uploads/2017/11/CATF_Pub_FumesAcrossTheFenceLine.pdf. (Accessed: February 24, 2019).

share of the health risks amounts to 51.3 percent while the low income share amounts to 19.0 percent.[2091]

One analysis at both the national and local levels, however, found that while "there are unquestionably environmental justice issues in certain areas surrounding refineries…drawing conclusions at a national level is much murkier."[2092] There is evidence of proximity of minority and low-income populations to other types of industrial facilities at the national level.[2093, 2094, 2095] Yet, with respect to refineries, it seems that while there is clear case-study evidence, national-level data do not demonstrate a consistent correlation between oil refineries and a higher prevalence of minority or low-income populations. In fact, performing a multivariate statistical analysis, one study found little support for the hypothesis that minority or low-income populations are more likely to live near oil refineries.[2096] At the national level, these studies demonstrate no clear evidence that minority and low-income populations are overrepresented in the populations close to oil refineries.

The potential increase in fuel production and consumption projected as a result of this rulemaking (compared to the No Action Alternative) could lead to an increase in upstream emissions of criteria and toxic air pollutants due to increased extraction, refining, and transportation of fuel. [Text Forthcoming] To the extent that minority and low-income populations live closer to oil refining facilities, these populations may be more likely to be adversely affected by these emissions. However, as noted, a correlation between proximity to oil refineries and the prevalence of minority and low-income populations has not been established in the scientific literature. Therefore, disproportionate impacts on minority and low-income populations due to their proximity to oil refineries are not foreseeable. In addition, the

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[2091] Ash, M., J.K. Boyce, G. Chang, M. Pastor, J. Scoggins, and J. Tran. *Justice in the Air: Tracking Toxic Poulltion from America's Industries and Companies to our States, Cities, and Neighborhoods*. Political Economy Research Institute at the University of Massachusetts, Amherst and the Program for Environmental and Regional Equity at the University of Southern California (2009). Available at: https://dornsife.usc.edu/assets/sites/242/docs/justice_in_the_air_web.pdf. (Accessed: February 24, 2019).

[2092] Fischbeck, P.S., D. Gerard, B. McCoy, and J. Hyun. *Using GIS to Explore Environmental Justice Issues: The Case of US Petroleum Refineries. Center for the Study and Improvement of Regulation*: Carnegie Mellon University. 18 pp (2006). Available at: https://www.researchgate.net/publication/242296191_Using_GIS_to_Explore_Environmental_Justice_Issues_The_Case_of_US_Petroleum_Refineries. (Accessed: March 1, 2018).

[2093] Mohai, P., P.M. Lantz, J. Morenoff, J.S. House, and R.P. Mero. *Racial and Socioeconomic Disparities in Residential Proximity to Polluting Industrial Facilities: Evidence from the Americans' Changing Lives Study*. American Journal of Public Health 99(S3):S649–S656 (2009). doi:10.2105/AJPH.2007.131383. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2774179/pdf/S649.pdf. (Accessed: March 2, 2018).

[2094] Graham, J.D., N.D. Beaulieu, D. Sussman, M. Sadowitz, and Y.C. Li. *Who Lives Near Coke Plants and Oil Refineries? An Exploration of the Environmental Inequity Hypothesis*. Risk Analysis 19(2):171–186 (1999). doi:10.1023/A:1006965325489. Green, R.S., S. Smorodinsky, J.J. Kim, R. McLaughlin, and B. Ostro. *Proximity of California public schools to busy roads*. Environmental Health Perspectives 112 (1):61–66 (2004). Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1241798/. (Accessed: May 31, 2018).

[2095] Jerrett, M., R.T. Burnett, P. Kanaroglou, J. Eyles, N. Finkelstein, C. Giovis, and J.R. Brook. *A GIS-Environmental Justice Analysis of Particulate Air Pollution in Hamilton, Canada*. Environment and Planning A 33(6):955–973 (2001). doi:10.1068/a33137.

[2096] Graham et al. (1999).

magnitude of the change in emissions relative to the baseline is minor and would not be characterized as high and adverse.

(2) Proximity to High-Traffic Roadways

Concentrations of many air pollutants are elevated near high-traffic roadways. Therefore, proximity to high-traffic roadways could result in adverse cardiovascular and respiratory impacts, among other possible impacts.[2097, 2098, 2099, 2100, 2101, 2102, 2103] One study demonstrated that students at schools in Michigan closer to major highways had a higher risk of respiratory and neurological disease and were more likely to fail to meet the state standard, after controlling for other variables.[2104] If minority and low-income populations disproportionately live near such roads, then an environmental justice issue may be present. The agencies reviewed existing scholarly literature examining the potential for disproportionate exposure among minorities and people with low socioeconomic status. The agencies conducted an evaluation of two national datasets: the U.S. Census Bureau's American Housing Survey for calendar year 2009 and the U.S. Department of Education's database of school locations.

Compared to the previous discussion regarding proximity to oil refineries, studies have more consistently demonstrated a disproportionate prevalence of minority and low-income populations living near mobile sources of pollutants. In certain locations in the United States, for example, there is consistent evidence that populations or schools near roadways typically include

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[2097] HEI (Health Effects Institute). 2010. Traffic-Related Air Pollution: A Critical Review of the Literature on Emissions, Exposure and Health Effects. Special Report 17. Health Effects Institute: Boston, MA:. HEI Panel on the Health Effects of Traffic-Related Air Pollution, 386 pp. Available at: https://www.healtheffects.org/system/files/SR17Traffic%20Review.pdf. (Accessed: March 3, 2018).

[2098] Heinrich, J. and H.-E. Wichmann. 2004. Traffic Related Pollutants in Europe and their Effect on Allergic Disease. *Current Opinion in Allergy and Clinical Immunology* 4(5):341–348.

[2099] Salam, M.T., T. Islam, and F.D. Gilliland. 2008. Recent Evidence for Adverse Effects of Residential Proximity to Traffic Sources on Asthma. *Current Opinion in Pulmonary Medicine* 14(1):3–8. doi:10.1097/MCP.0b013e3282f1987a.

[2100] Samet, J.M. 2007. Traffic, Air Pollution, and Health. *Inhalation Toxicology* 19(12):1021–1027. doi:10.1080/08958370701533541.

[2101] Adar, S. and J. Kaufman. 2007. Cardiovascular Disease and Air Pollutants: Evaluating and Improving Epidemiological Data Implicating Traffic Exposure. *Inhalation Toxicology* 19(S1):135–149. doi:10.1080/08958370701496012.

[2102] Wilker, E.H., E. Mostofsky, S.H. Lue, D. Gold, J. Schwartz, G.A. Wellenius, and M.A. Mittleman. 2013. Residential Proximity to High-Traffic Roadways and Poststroke Mortality. *Journal of Stroke and Cerebrovascular Diseases* 22(8):e366–e372. doi:10.1016/j.jstrokecerebrovasdis.2013.03.034. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4066388/. (Accessed: March 6, 2018).

[2103] Hart, J.E., E.B. Rimm, K.M. Rexrode, and F. Laden. 2013. Changes in Traffic Exposure and the Risk of Incident Myocardial Infarction and All-cause Mortality. *Epidemiology* 24(5):734–742.

[2104] Kweon, B-S., P. Mohai, S. Lee, and A.M. Sametshaw. 2016. Proximity of Public Schools to Major Highways and Industrial Facilities, and Students' School Performance and Health Hazards. *Environment and Planning B: Urban Analytics and City Science* 45(2):312–329. doi.org/10.1177/0265813516673060.

a greater percentage of minority or low-income residents.[2105, 2106, 2107, 2108, 2109, 2110, 2111] In California, minorities and low-income populations are disproportionately likely to live near a major roadway compared to the general population.[2112] This proximity has been attributed to cause or exacerbate other related health impacts, such as asthma,[2113, 2114, 2115] and may be due to multiple factors.[2116] In general, studies such as these demonstrate trends in specific locations in the United States that may be indicative of broader national trends.

Fewer studies have been conducted at the national level, yet those that do exist also demonstrate a correlation between minority and low-income status and proximity to roadways.[2117, 2118] For example, one study found that greater traffic volumes and densities at the

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[2105] Green, R.S., S. Smorodinsky, J.J. Kim, R. McLaughlin, and B. Ostro. *Proximity of California public schools to busy roads*. Environmental Health Perspectives 112 (1):61–66 (2004). Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1241798/. (Accessed: May 31, 2018).

[2106] Wu, Y-C.; Batterman, S.A. *Proximity of schools in Detroit, Michigan to automobile and truck traffic*. Journal of Exposure Science and Environmental Epidemiology 16(5): 457-470 (2006). doi:10.1038/sj.jes.7500484. Available at: http://www.nature.com/articles/7500484. (Accessed: May 31, 2018).

[2107] Chakraborty, J.; and P.A. Zandbergen. *Children at risk: measuring racial/ethnic disparities in potential exposure to air pollution at school and home*. Journal of Epidemiology & Community Health 61:1074-1079 (2007). doi: 10.1136/jech.2006.054130.

[2108] Depro, B., and C. Timmins. Mobility and Environmental Equity: *Do Housing Choices Determine Exposure to Air Pollution?* North Carolina State University and RTI International, Duke University and NBER (2008). Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.586.7164&rep=rep1&type=pdf. (Accessed: May 31, 2018).

[2109] Marshall, J.D. *Environmental inequality: air pollution exposures in California's South Coast Air Basin*. Atmospheric Environment 42(21):5499-5503 (2008).

[2110] Su, J. G., T. Larson, T. Gould, M. Cohen, and M. Buzzelli. *Transboundary air pollution and environmental justice: Vancouver and Seattle compared*. GeoJournal 75(6):595-608 (2010). doi: 10.1007/s10708-009-9269-6.

[2111] Su, J. G., M. Jarrett, A. de Nazelle, and J. Wolch. *Does exposure to air pollution in urban parks have socioeconomic, racial or ethnic gradients?* Environmental Research 111 (3):319-328 (2011). doi: 10.1016/j.envres.2011.01.002.

[2112] Carlson, A.E. *The Clean Air Act's Blind Spot: Microclimates and Hotspot Pollution*. 65 UCLA Law Review 1036 (2018).

[2113] Gunier, R.B., A. Hertz, J. Von Behren, and P. Reynolds. *Traffic density in California: socioeconomic and ethnic differences among potentially exposed children*. Journal of Exposure Analysis and Environmental Epidemiology 13(3):240–46 (2003). doi:10.1038/sj.jea.7500276.

[2114] Meng, Y-Y., M. Wilhelm, R.P. Rull, P. English, S. Nathan, and B. Ritz. *Are frequent asthma symptoms among low-income individuals related to heavy traffic near homes, vulnerabilities, or both?* Annals of Epidemiology 18:343-350 (2008). doi:10.1016/j.annepidem.2008.01.006.

[2115] Khreis, H., C. Kelly, J. Tate, R. Parslow, K. Lucas, and M. Nieuwenhuijsen. *Exposure to traffic-related air pollution and risk of development of childhood asthma: A systematic review and meta-analysis*. Environment International 100:1–31 (2017). https://doi.org/10.1016/j.envint.2016.11.012.

[2116] Depro, B.; Timmins, C. Mobility and environmental equity: *do housing choices determine exposure to air pollution?* North Caroline State University Center for Environmental and Resource Economic Policy (2008).

[2117] Tian, N., J. Xue, and T. M. Barzyk. *Evaluating socioeconomic and racial differences in traffic-related metrics in the United States using a GIS approach*. Journal of Exposure Science and Environmental Epidemiology 23 (2):215 (2013). doi: 10.1038/jes.2012.83. Available at: http://www.nature.com/articles/jes201283. (Accessed: May 31, 2018).

[2118] Boehmer, T.K., S.L. Foster, J.R. Henry, E.L. Woghiren-Akinnifesi, and F.Y. Yip. *Residential Proximity to Major Highways – United States, 2010*. Morbidity and Mortality Weekly Report 62(3):46–50 (2013). Available at: http://www.cdc.gov/mmwr/preview/mmwrhtml/su6203a8.htm. (Accessed: February 26, 2018).

national level are associated with larger shares of minority and low-income populations living in the vicinity.[2119] Another study found that schools with minority and underprivileged[2120] children were disproportionately located within 250 meters of a major roadway.[2121]

The agencies analyzed two national databases that allowed evaluation of whether homes and schools were located near a major road and whether disparities in exposure may be occurring in these environments. The American Housing Survey (AHS) includes descriptive statistics of over 70,000 housing units across the nation. The study survey is conducted every two years by the U.S. Census Bureau. The second database the agencies analyzed was the U.S. Department of Education's Common Core of Data, which includes enrollment and location information for schools across the U.S.

In analyzing the 2009 AHS, the focus was on whether or not a housing unit was located within 300 feet of a "4-or-more lane highway, railroad, or airport."[2122] Whether there were differences between households in such locations compared with those in locations farther from these transportation facilities was analyzed.[2123] Other variables, such as land use category, region of country, and housing type, were included. Homes with a nonwhite householder were found to be 22–34 percent more likely to be located within 300 feet of these large transportation facilities than homes with white householders. Homes with a Hispanic householder were 17–33 percent more likely to be located within 300 feet of these large transportation facilities than homes with non-Hispanic householders. Households near large transportation facilities were, on average, lower in income and educational attainment, more likely to be a rental property, and more likely to be located in an urban area compared with households more distant from transportation facilities.

In examining schools near major roadways, the Common Core of Data (CCD) from the U.S. Department of Education, which includes information on all public elementary and secondary schools and school districts nationwide, was examined.[2124] To determine school proximities to major roadways, a geographic information system (GIS) to map each school and roadways based on the U.S. Census's TIGER roadway file was used.[2125] Minority students were

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[2119] Rowangould, G.M. *A Census of the US Near-roadway Population: Public Health and Environmental Justice Considerations*. Transportation Research Part D: Transport and Environment 25:59–67 (2013). doi:10.1016/j.trd.2013.08.003.

[2120] Public schools were determined to serve predominantly underprivileged students if they were eligible for Title I programs (federal programs that provide funds to school districts and schools with high numbers or high percentages of children who are disadvantaged) or had a majority of students who were eligible for free/reduced-price meals under the National School Lunch and Breakfast Programs.

[2121] Kingsley, S.L., M.N. Eliot, L. Carlson, J. Finn, D.L. MacIntosh, H.H. Suh, and G.A. Wellenius. *Proximity of US Schools to Major Roadways: A Nationwide Assessment*. Journal of Exposure Science and Environmental Epidemiology 24(3):253–259 (2014). doi:10.1038/jes.2014.5.

[2122] This variable primarily represents roadway proximity. According to the Central Intelligence Agency's World Factbook, in 2010, the United States had 6,506,204 km of roadways, 224,792 km of railways, and 15,079 airports. Highways thus represent the overwhelming majority of transportation facilities described by this factor in the AHS.

[2123] Bailey, C. (2011) Demographic and Social Patterns in Housing Units Near Large Highways and other Transportation Sources. Memorandum to docket.

[2124] http://nces.ed.gov/ccd/.

[2125] Pedde, M.; Bailey, C. Identification of Schools within 200 Meters of U.S. Primary and Secondary Roads. Memorandum to the docket (2011).

found to be overrepresented at schools within 200 meters of the largest roadways, and schools within 200 meters of the largest roadways also had higher than expected numbers of students eligible for free or reduced-price lunches. For example, Black students represent 22 percent of students at schools located within 200 meters of a primary road, whereas Black students represent 17 percent of students in all U.S. schools. Hispanic students represent 30 percent of students at schools located within 200 meters of a primary road, whereas Hispanic students represent 22 percent of students in all U.S. schools.

Overall, there is substantial evidence that the population who lives or attends school near major roadways are more likely to be minority or low income. Total downstream (tailpipe) emissions of criteria and toxic air pollutants for cars and light trucks are projected to [Text Forthcoming]. These analyses demonstrate that to the extent minority and low-income populations live or attend schools near major roadways, a potential for disproportionate impacts exists. However, as emissions changes are anticipated to be minor compared to total tailpipe emissions for these vehicles, the impacts to minority or low-income populations are not considered high and adverse.

The agencies used the standards that were discussed in the 2012 rulemaking as the baseline for this rulemaking. Therefore, the agencies project increases in certain air pollutants for purposes of this analysis. However, as discussed above, one impact of the standards finalized in this rulemaking is to reduce the up-front cost of new and used vehicles. Low income populations may benefit most from the reduction in cost of acquiring newer vehicles, which generally are more fuel efficient and have lower air pollutant emissions than older vehicles (i.e., the vehicles on the road in the years preceding the effectiveness of this rulemaking rather than the hypothetical vehicles that would have been produced under the standards discussed in the 2012 rulemaking). This cost reduction may have the effect of encouraging the quicker adoption of cleaner vehicles in low income communities, which could result in air quality and health benefits for those who live or attend school in proximity to the roadways where they are operated. To the degree to which minority populations may also live in proximity to these roadways, they would also experience benefits, thereby mitigating the disparity in racial, ethnic, and economically based exposures.

(3) Other Vulnerabilities to Health Impacts of Air Pollutants

Independent of their proximity to pollution sources, minority and low-income populations could be more vulnerable to the health impacts of pollutants. Reports from the U.S. Department of Health and Human Services have stated that minority and low-income

populations tend to have less access to health care services, and the services received are more likely to suffer with respect to quality.[2126, 2127, 2128]

In a similar vein, other studies show that low income can exacerbate the health impacts of air pollution.[2129, 2130] People with low socioeconomic status often live in neighborhoods with multiple stressors and higher rates of health risk factors, including reduced health insurance coverage rates, higher smoking and drug use rates, limited access to fresh food, visible neighborhood violence, and elevated rates of obesity and some diseases such as asthma, diabetes, and ischemic heart disease. Although questions remain, several studies find stronger associations between air pollution and health in locations with such chronic neighborhood stress, suggesting that populations in these areas may be more susceptible to the effects of air pollution.[2131, 2132, 2133, 2134] Household-level stressors such as parental smoking and relationship stress also may increase susceptibility to the adverse effects of air pollution.[2135, 2136]

[2126] U.S. Department of Health and Human Services (HHS). National Healthcare Disparities Report. U.S. Department of Health and Human Service. Rockville, MD, Agency for Healthcare Research and Quality (2003). Available at: http://archive.ahrq.gov/qual/nhdr03/nhdr03.htm. (Accessed: March 3, 2018).

[2127] HHS. Minority Health: Recent Findings. Agency for Healthcare Research Quality (2013). Last revised: February 2013. Available at: https://www.ahrq.gov/research/findings/factsheets/minority/minorfind/index.html. (Accessed: March 3, 2018).

[2128] HHS. 2016 National Healthcare Disparities Report. U.S. Department of Health and Human Service (2017). Rockville, MD. Agency for Healthcare Research and Quality. Available at: https://www.ahrq.gov/research/findings/nhqrdr/nhqdr16/summary.html. (Accessed: September 20, 2017).

[2129] O'Neill, M.S., M. Jerrett, I. Kawachi, J.I. Levy, A.J. Cohen, N. Gouveia, P. Wilkinson, T. Fletcher, L. Cifuentes, and J. Schwartz. *Health, Wealth, and Air Pollution: Advancing Theory and Methods*. Environmental Health Perspectives 111(16):1861–1870 (2003), doi: 10.1289/ehp.6334. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1241758/pdf/ehp0111-001861.pdf. (Accessed: February 24, 2019).

[2130] Ostro, B., R. Broadwin, S. Green, W.Y. Feng, and M. Lipsett. *Fine Particulate Air Pollution and Mortality in Nine California Counties: Results from CALFINE*. Environmental Health Perspectives 114(1): 29–33 (2006).

[2131] Clougherty, J.E.; Kubzansky, L.D. *A framework for examining social stress and susceptibility to air pollution in respiratory health. Environ Health Perspect* 117: 1351-1358 (2009). Doi:10.1289/ehp.0900612 [Online at http://dx.doi.org].

[2132] Clougherty, J.E.; Levy, J.I.; Kubzansky, L.D.; Ryan, P.B.; Franco Suglia, S.; Jacobson Canner, M.; Wright, R.J. *Synergistic effects of traffic-related air pollution and exposure to violence on urban asthma etiology*. Environ Health Perspect 115: 1140-1146 (2007). doi:10.1289/ehp.9863 [Online at http://dx.doi.org].

[2133] Finkelstein, M.M.; Jerrett, M.; DeLuca, P.; Finkelstein, N.; Verma, D.K.; Chapman, K.; Sears, M.R. *Relation between income, air pollution and mortality: a cohort study*. Canadian Med Assn J 169: 397-402 (2003).

[2134] Shankardass, K.; McConnell, R.; Jerrett, M.; Milam, J.; Richardson, J.; Berhane, K. *Parental stress increases the effect of traffic-related air pollution on childhood asthma incidence*. Proc Natl Acad Sci 106: 12406-12411 (2009). doi:10.1073/pnas.0812910106 [Online at http://dx.doi.org].

[2135] Lewis, A.S.; Sax, S.N.; Wason, S.C.; Campleman, S.L. *Non-chemical stressors and cumulative risk assessment: an overview of current initiatives and potential air pollutant interactions*. Int J Environ Res Public Health 8: 2020-2073 (2011). Doi:10.3390/ijerph8062020 [Online at http://dx.doi.org].

[2136] Rosa, M.J.; Jung, K.H.; Perzanowski, M.S.; Kelvin, E.A.; Darling, K.W.; Camann, D.E.; Chillrud, S.N.; Whyatt, R.M.; Kinney, P.L.; Perera, F.P.; Miller, R.L *Prenatal exposure to polycyclic aromatic hydrocarbons, environmental tobacco smoke and asthma*. Respir Med (In press) (2010). doi:10.1016/j.rmed.2010.11.022 [Online at http://dx.doi.org].

These factors would likely exacerbate the findings described above regarding upstream and downstream emissions as they impact minority and low income populations. The degree to which this would occur, however, cannot feasibly be quantified for purposes of this analysis.

b) Climate Change and Carbon Emissions

Some areas most vulnerable to climate change tend to have a higher concentration of minority and low-income populations, potentially putting these communities at higher risk from climate variability and climate-related extreme weather events.[2137] For example, urban areas tend to have pronounced social inequities that could result in disproportionately larger minority and low-income populations than those in the surrounding nonurban areas.[2138] Urban areas are also subject to the most substantial temperature increases from climate change because of the urban heat island effect.[2139, 2140, 2141] Climate change impacts on temperatures could, in turn, affect the number and severity of outbreaks of vector-borne illnesses.[2142, 2143] Taken together, these tendencies demonstrate a potential for disproportionate impacts on minority and low-income populations in urban areas. Low-income populations in coastal urban areas, which are vulnerable to increases in flooding as a result of projected sea-level rise, larger storm surges, and human settlement in floodplains, could also be disproportionately affected by climate change because they are less likely to have the means to evacuate quickly in the event of a natural disaster and, therefore, are at greater risk of injury and loss of life.[2144, 2145]

Independent of their proximity to locations of potentially high impact from climate change, minority and low-income populations could be more vulnerable to the health impacts of climate change. Increases in heat-related morbidity and mortality because of higher overall and extreme temperatures are likely to affect minority and low-income populations disproportionately, partially because of limited access to air conditioning and high energy

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[2137] U.S. Global Change Research Program (GCRP). Global Climate Change Impacts in the United States: The Third National Climate Assessment. U.S. Global Change Research Program. [Melillo, J.M, T.C. Richmond, and G.W. Yohe (Eds.)]. U.S. Government Printing Office: Washington, D.C. 841 pp (2014). doi:10.7930/J0Z31WJ2. Available at: http://nca2014.globalchange.gov/report. (Accessed: February 27, 2018).
[2138] GCRP (2014).
[2139] GCRP (2014).
[2140] Knowlton, K., B. Lynn, R.A. Goldberg, C. Rosenzweig, C. Hogrefe, J.K. Rosenthal, and P.L. Kinney. Projecting *Heat-related Mortality Impacts under a Changing Climate in the New York City Region.* American Journal of Public Health 97(11):2028–2034 (2007). doi:10.2105/AJPH.2006.102947. Available in: http://ajph.aphapublications.org/cgi/content/full/97/11/2028. (Accessed: March 4, 2018).
[2141] EPA. Heat Island Effect. U.S. Environmental Protection Agency (2017). Last revised: February 20, 2018. Available at: https://www.epa.gov/heat-islands. (Accessed: February 28, 2018.).
[2142] GCRP (2014).
[2143] GCRP. The Impacts of Climate Change on Human Health in the United States, A Scientific Assessment (2016). April 2016. Available at: https://health2016.globalchange.gov. (Accessed: February 28, 2018).
[2144] GCRP, Global Climate Impacts in the United States (2009). Cambridge, United Kingdom and New York, NY, USA. [Karl, T.R., J.M. Melillo, and T.C. Peterson (Eds.).] Cambridge University Press: Cambridge, UK. pp. 196.
[2145] GCRP (2014).

costs.[2146, 2147, 2148, 2149] Native American tribes and Alaskan Native villages are also more susceptible to the impacts of climate change, as these groups often disproportionately rely on natural resources for livelihoods, medicines, and cultural and spiritual purposes.[2150] Moreover, coastal tribal communities may have to relocate because of sea-level rise, erosion, and permafrost thaw.[2151] Together, this information indicates that the same set of potential environmental effects (e.g., heat increases and sea level rise) may disproportionately affect minority and low-income populations because of socioeconomic circumstances or histories of discrimination and inequity.

With respect to tailpipe carbon emissions, such emissions do not have direct impacts on minority and low income populations, but rather may have potential indirect impacts through global climate change. The increases in CO_2 and related gases associated with the standards will affect climate change projections, and the agencies have estimated marginal increases in projected global mean surface temperatures and sea-level rise in this preamble, the accompanying RIA, and NHTSA's FEIS. Within settlements experiencing climate change, certain parts of the population may be especially vulnerable; these include the poor, the elderly, those already in poor health, the disabled, those living alone, and/or indigenous populations dependent on one or a few resources. However, the potential increases in climate change impacts resulting from this rule are so small and incremental that the impacts are not considered high and adverse on these populations.

c) Conclusion

Based on the foregoing, the agencies have determined that this rulemaking (and alternatives considered) would not result in disproportionately high and adverse human health or environmental effects on minority or low-income populations. This rulemaking would set standards nationwide, and although minority and low-income populations may experience some

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[2146] EPA. 2009. Technical Support Document for Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the Clean Air Act. December 7, 2009. U.S. Environmental Protection Agency, Office of Atmospheric Programs, Climate Change Division: Washington, D.C. Available at: https://www.epa.gov/sites/production/files/2016-08/documents/endangerment_tsd.pdf. (Accessed: February 28, 2018).

[2147] O'Neill, M.S., A. Zanobetti, and J. Schwartz. *Disparities by Race in Heat-Related Mortality in Four US Cities: The Role of Air Conditioning Prevalence*. Journal of Urban Health 82(2):191–197 (2005). doi:10.1093/jurban/jti043. Available at: http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3456567/pdf/11524_2006_Article_375.pdf. (Accessed: March 4, 2018).

[2148] GCRP (2014).

[2149] Harlan, S.L. and D.M. Ruddell. *Climate Change and Health in Cities: Impacts of Heat and Air Pollution and Potential Co-Benefits from Mitigation and Adaptation*. Current Opinion in Environmental Sustainability 3(3):126–134 (2011). doi: 10.1016/j.cosust.2011.01.001.

[2150] National Tribal Air Association. 2009. Impacts of climate change on Tribes in the United States. Submitted December 11, 2009 to Assistant Administrator Gina McCarthy, USEPA, Office of Air and Radiation. Available at: http://www.epa.gov/air/tribal/pdfs/Impacts%20of%20Climate%20Change%20on %20Tribes%20in%20the%20United%20States.pdf. (Accessed: February 24, 2019).

[2151] Maldonado, J., C. Shearer, R. Bronen, K. Peterson, and H. Lazrus. *The Impact of Climate Change on Tribal Communities in the US: Displacement, Relocation, and Human Rights*. Climatic Change 120(3):601–614 (2013).

disproportionate effects, in particular locations, the overall impacts on human health and the environment would not be "highand adverse" under EO 12898.

Furthermore, the agencies note that there are no mitigation measures or alternatives available as part of this action that could fulfill the respective statutory missions of the agencies and that would address the issues discussed in Section VIII (e.g., technological feasibility and economic practicability) or avoid or reduce any disproportionate effects in particular locations experienced by minority and low-income populations. The impacts described in this analysis would result from air pollutant and CO_2 emissions that are the direct effect of the levels of stringency selected by the agencies. However, for the reasons described in Section VIII, the agencies cannot select a higher level of stringency. While the agencies have considered the potential impacts described in this analysis, there is a substantial need, based on the overall public interest, to address the costs associated with the standards discussed in the 2012 rulemaking. More stringent alternatives would have severe adverse social and economic costs, as described in Section VIII, and necessitate the level of standards finalized in this rulemaking.

12. Executive Order 13045: "Protection of Children from Environmental Health Risks and Safety Risks"

This action is subject to EO 13045 (62 FR 19885, April 23, 1997) because it is an economically significant regulatory action as defined by EO 12866, and the agencies have reason to believe that the environmental health or safety risks related to this action may have a disproportionate effect on children. Specifically, children are more vulnerable to adverse health effects related to mobile source emissions, as well as to the potential long-term impacts of climate change. Pursuant to EO 13045, NHTSA and EPA must prepare an evaluation of the environmental health or safety effects of the planned regulation on children and an explanation of why the planned regulation is preferable to other potentially effective and reasonably feasible alternatives considered by the agencies. Further, this analysis may be included as part of any other required analysis.

This preamble and NHTSA's Final EIS discuss air quality, climate change, and their related environmental and health effects, noting where these would disproportionately affect children. The EPA Administrator has also discussed the impact of climate-related health effects on children in the Endangerment and Cause or Contribute Findings for Greenhouse Gases Under Section 202(a) of the Clean Air Act (74 FR 66496, December 15, 2009). In addition, this preamble explains why the agencies' final standards are preferable to other alternatives considered. Together, this preamble and NHTSA's Final EIS satisfy the agencies' responsibilities under EO 13045.

F. Regulatory Flexibility Act

Pursuant to the Regulatory Flexibility Act (5 U.S.C. 601 *et seq.*, as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996), whenever an agency is required to publish a notice of proposed rulemaking or final rule, it must prepare and make available for public comment a regulatory flexibility analysis that describes the effect of the rule on small entities (*i.e.*, small businesses, small organizations, and small governmental

jurisdictions). No regulatory flexibility analysis is required if the head of an agency certifies the rule will not have a significant economic impact on a substantial number of small entities. SBREFA amended the Regulatory Flexibility Act to require Federal agencies to provide a statement of the factual basis for certifying that a rule will not have a significant economic impact on a substantial number of small entities.

Two comments argued that the agencies should prepare a regulatory flexibility analysis and convene a small business review panel to assess the impacts in accordance with the Regulatory Flexibility Act, 5 U.S.C. 601 *et seq.*, as amended by SBREFA.[2152] The agencies considered these comments and the impacts of this rule under the Regulatory Flexibility Act and certify that this rule will not have a significant economic impact on a substantial number of small entities. The following is the agencies' statement providing the factual basis for this certification pursuant to 5 U.S.C. 605(b).

Small businesses are defined based on the North American Industry Classification System (NAICS) code.[2153] One of the criteria for determining size is the number of employees in the firm. For establishments primarily engaged in manufacturing or assembling automobiles, as well as light duty trucks, the firm must have less than 1,500 employees to be classified as a small business. This rule would affect motor vehicle manufacturers. As shown in Table X-1Table X-1, the agencies have identified 15 small manufacturers of passenger cars, light trucks, and SUVs of electric, hybrid, and internal combustion engines.[2154] The agencies acknowledge that some newer manufacturers may not be listed. However, those new manufacturers tend to have transportation products that are not part of the light-duty vehicle fleet and have yet to start production of light-duty vehicles. Moreover, NHTSA does not believe that there are a "substantial number" of these newer companies.[2155]

Table X-1 - Small Domestic Vehicle Manufacturers

Manufacturers	Founded	Employees[2156]	Estimated Annual Production[2157]	Sale Price per Unit
Karma Automotive	2014	625	900	$130,000
BXR Motors	2008	< 10	< 100	$155,000 to $185,000

[2152] *See* National Coalition for Advanced Transportation (NCAT) Comment, Docket No. NHTSA-2018-0067-11969, at 64-65; Workhorse Group, Inc. Comment, Docket No. NHTSA-2018-0067-12215, at 1-2.

[2153] Classified in NAICS under Subsector 336—Transportation Equipment Manufacturing for Automobile Manufacturing (336111), Light Truck (336112), and Heavy Duty Truck Manufacturing (336120). https://www.sba.gov/document/support-table-size-standards.

[2154] Two comments pointed out that Workhorse Group Inc. was not listed as a small domestic vehicle manufacturer in Table XII-1 of the proposal. *See* National Coalition for Advanced Transportation (NCAT) Comment, Docket No. NHTSA-2018-0067-11969, at 64-65; Workhorse Group, Inc. Comment, Docket No. NHTSA-2018-0067-12215, at 1-2. Workhorse Group has been added to the table here, but neither its addition nor the existence of a small number of other new small manufacturers does not alter the conclusion that this rule will not have a significant economic impact on a substantial number of small entities.

[2155] 5 U.S.C. 605(b).

[2156] Estimated number of employees as of 2018, source: Linkedin.com.

[2157] Rough estimate of light duty vehicle production for model year 2017.

Falcon Motorsports	2009	5	< 100	$300,000 to $400,000
Lucra Cars	2005	8	< 100	$100,000
Lyons Motor Car	2012	< 10	< 100	$1,400,000
Rezvani Motors	2014	6	< 100	$95,000 to $270,000
Rossion Automotive	2007	6	< 100	$90,000
Saleen	1984	51	< 100	$100,000
Shelby American	1962	61	< 100	$60,000 to $250,000
Panoz	1988	20	< 100	$155,000 to $175,000
Faraday Future	2014	790	0	$200,000 to $300,000
Lucid Motor Car	2007	269	0	$60,000
Rivian Automotive	2009	208	0	N/A
SF Motors	2016	204	0	N/A
Workhorse Group	2007	125	0	$52,000

NHTSA believes that the rulemaking would not have a significant economic impact on the small vehicle manufacturers because under 49 CFR part 525, passenger car manufacturers making less than 10,000 vehicles per year can petition NHTSA to have alternative standards set for those manufacturers. These manufacturers do not currently meet the 27.5 mpg standard and must already petition the agency for relief. If the standard is raised, it has no meaningful impact on these manufacturers—they still must go through the same process and petition for relief. Given there already is a mechanism for relieving burden on small businesses, which is the purpose of the Regulatory Flexibility Act, a regulatory flexibility analysis was not prepared.

Two comments argued that small manufacturers of electric vehicles would face a significant economic impact because their ability to earn credits would be "substantially diminished."[2158] The method for earning credits applies equally across manufacturers and does not place small entities at a significant competitive disadvantage. In any event, even if the rule had a "significant economic impact" on these small EV manufacturers, the amount of these companies is not "a substantial number."[2159] For these reasons, their existence does not alter the agencies' analysis of the applicability of the Regulatory Flexibility Act. EPA believes this rulemaking would not have a significant economic impact on a substantial number of small entities under the Regulatory Flexibility Act, as amended by the Small Business Regulatory Enforcement Fairness Act. EPA is exempting from the CO_2 standards any manufacturer, domestic or foreign, meeting SBA's size definitions of small business as described in 13 CFR 121.201. EPA adopted the same type of exemption for small businesses in the 2017 and later rulemaking. EPA estimates that small entities comprise less than 0.1 percent of total annual vehicle sales and exempting them will have a negligible impact on the CO_2 emissions reductions from the standards. Because EPA is exempting small businesses from the CO_2 standards, the agency certifies that the rule will not have a significant economic impact on a substantial number

[2158] National Coalition for Advanced Transportation (NCAT) Comment, Docket No. NHTSA-2018-0067-11969, at 65; Workhorse Group, Inc. Comment, Docket No. NHTSA-2018-0067-12215, at 2.
[2159] 5 U.S.C. 605.

of small entities. Therefore, EPA has not conducted a Regulatory Flexibility Analysis or a SBREFA SBAR Panel for the rule.

EPA regulations allow small businesses voluntarily to waive their small business exemption and optionally to certify to the CO_2 standards. This option allows small entity manufacturers to earn CO_2 credits under the CO_2 program, if their actual fleetwide CO_2 performance is better than their fleetwide CO_2 target standard. However, the exemption waiver is optional for small entities and thus the agency believes that manufacturers opt into the CO_2 program if it is economically advantageous for them to do so, for example in order to generate and sell CO_2 credits. Therefore, EPA believes this voluntary option does not affect EPA's determination that the standards will impose no significant adverse impact on small entities.

G. Executive Order 13132 (Federalism)

Executive Order 13132 requires Federal agencies to develop an accountable process to ensure "meaningful and timely input by State and local officials in the development of regulatory policies that have federalism implications." The Order defines the term "[p]olicies that have federalism implications" to include regulations that have "substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government." Under the Order, agencies may not issue a regulation that has federalism implications, that imposes substantial direct compliance costs, unless the Federal government provides the funds necessary to pay the direct compliance costs incurred by State and local governments, or the agencies consult with State and local officials early in the process of developing the proposed regulation. The agencies complied with the Order's requirements.

See Section [xxx] above for further detail on the agencies' assessment of the federalism implications of this proposal.

H. Executive Order 12988 (Civil Justice Reform)

Pursuant to Executive Order 12988, "Civil Justice Reform,"[2160] NHTSA has considered whether this rulemaking would have any retroactive effect. This proposed rule does not have any retroactive effect.

I. Executive Order 13175 (Consultation and Coordination With Indian Tribal Governments)

This final rule does not have tribal implications, as specified in Executive Order 13175 (65 FR 67249, November 9, 2000). This rule will be implemented at the Federal level and impose compliance costs only on vehicle manufacturers. Thus, Executive Order 13175 does not apply to this rule. Some comments complained that the agencies have not consulted or

[2160] 61 FR 4729 (Feb. 7, 1996).

coordinated with Native American communities and Indian Tribes in promulgating this rule.[2161] Executive Order 13175 requires consultation with Tribal officials when agencies are developing policies that have "substantial direct effects" on Tribes and Tribal interests.[2162] Even accepting the comments' description of the effects of the rule, they have identified only indirect effects of the standards on Tribal interests.[2163]

J. Unfunded Mandates Reform Act

Section 202 of the Unfunded Mandates Reform Act of 1995 (UMRA) requires Federal agencies to prepare a written assessment of the costs, benefits, and other effects of a proposed or final rule that includes a Federal mandate likely to result in the expenditure by State, local, or Tribal governments, in the aggregate, or by the private sector, of more than $100 million in any one year (adjusted for inflation with base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for 2016 results in $148 million (111.416/75.324 = 1.48).[2164] Before promulgating a rule for which a written statement is needed, section 205 of UMRA generally requires NHTSA and EPA to identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost-effective, or least burdensome alternative that achieves the objective of the rule. The provisions of section 205 do not apply when they are inconsistent with applicable law. Moreover, section 205 allows NHTSA and EPA to adopt an alternative other than the least costly, most cost-effective, or least burdensome alternative if the agency publishes with the rule an explanation of why that alternative was not adopted.

This rule will not result in the expenditure by State, local, or Tribal governments, in the aggregate, of more than $148 million annually, but it will result in the expenditure of that magnitude by vehicle manufacturers and/or their suppliers. In developing this rule, NHTSA and EPA considered a variety of alternative average fuel economy standards lower and higher than those previously proposed. The fuel economy standards for MYs 2021-2026 are the least costly, most cost-effective, and least burdensome alternative that achieve the objectives of the rule.

K. Regulation Identifier Number

The Department of Transportation assigns a regulation identifier number (RIN) to each regulatory action listed in the Unified Agenda of Federal Regulations. The Regulatory Information Service Center publishes the Unified Agenda in April and October of each year.

[2161] *See, e.g.*, CARB Comment, Docket No. NHTSA-2018-0067-11873, at 412; National Tribal Air Association Comment, Docket No. NHTSA-2018-0067-11948, at 4; Keweenaw Bay Indian Community Comment, Docket No. EPA-HQ-OAR-2018-0283-3325, at 1-2; Fond du Lac Band of Lake Superior Chippewa Comment, Docket No. EPA-HQ-OAR-2018-0283-4030, at 3; Sac and Fox Nation, Docket No. EPA-HQ-OAR-2018-0283-4159, at 4-5; The Leech Lake Band of Ojibwe Comment, Docket No. EPA-HQ-OAR-2018-0283-5931, at 4-5.
[2162] 65 FR 67249, 67249 (Nov. 6, 2000).
[2163] *See, e.g.*, National Tribal Air Association Comment, Docket No. NHTSA-2018-0067-11948, at 4.
[2164] Bureau of Economic Analysis, National Income and Product Accounts (NIPA), Table 1.1.9 Implicit Price Deflators for Gross Domestic Product. https://bea.gov/iTable/index_nipa.cfm.

The RIN contained in the heading at the beginning of this document may be used to find this action in the Unified Agenda.

L. National Technology Transfer and Advancement Act

Section 12(d) of the National Technology Transfer and Advancement Act (NTTAA) requires NHTSA and EPA to evaluate and use existing voluntary consensus standards in its regulatory activities unless doing so would be inconsistent with applicable law (*e.g.*, the statutory provisions regarding NHTSA's vehicle safety authority, or EPA's testing authority) or otherwise impractical.[2165]

Voluntary consensus standards are technical standards developed or adopted by voluntary consensus standards bodies. Technical standards are defined by the NTTAA as "performance-based or design-specific technical specification and related management systems practices." They pertain to "products and processes, such as size, strength, or technical performance of a product, process or material."

Examples of organizations generally regarded as voluntary consensus standards bodies include the American Society for Testing and Materials (ASTM), the Society of Automotive Engineers (SAE), and the American National Standards Institute (ANSI). If the agencies do not use available and potentially applicable voluntary consensus standards, they are required by the Act to provide Congress, through OMB, an explanation of the reasons for not using such standards.

For CO_2 emissions, EPA will collect data over the same tests that are used for the MY 2012-~~2016~~ to present CO_2 standards and for the CAFE program. This unified data collection will minimize the amount of testing done by manufacturers because manufacturers are already required to run these tests. ~~For A/C credits, EPA will use a consensus methodology developed by the Society of Automotive Engineers (SAE) and also a new A/C test. EPA knows of no consensus standard available for the A/C test.~~

Commented [A460]: DELTE: EPA is not establishing new test for AC as part of this final rule, therefore this text is not correct.

There are currently no voluntary consensus standards that NHTSA administers relevant to today's CAFE standards.

M. Department of Energy Review

In accordance with 49 U.S.C. 32902(j)(2), NHTSA submitted this rule to the Department of Energy for review.

N. Paperwork Reduction Act

The Paperwork Reduction Act (PRA) of 1995, Public Law 104-13,[2166] gives OMB authority to regulate matters regarding the collection, management, storage, and dissemination of certain information by and for the Federal government. It seeks to reduce the total amount of

[2165] 15 U.S.C. 272.
[2166] Codified at 44 U.S.C. 3501 *et seq.*

paperwork handled by the government and the public. NHTSA strives to reduce the public's information collection burden hours each fiscal year by streamlining external and internal processes.

To this end, NHTSA will continue to collect information to ensure compliance with its CAFE program. NHTSA will reinstate its previously-approved collection of information for Corporate Average Fuel Economy (CAFE) reports specified in 49 CFR part 537 (OMB control number 2127-0019), add the additional burden for reporting changes adopted in the October 15, 2012 final rule that recently came into effect (*see* 77 FR 62623), and account for the change in burden in this rule as well as for other CAFE reporting provisions required by Congress and NHTSA. NHTSA is also changing the name of this collection to represent more accurately the breadth of all CAFE regulatory reporting. Although NHTSA is adding additional burden hours to its CAFE report requirement in 49 CFR 537, the agency believes there will be a reduction in the overall paperwork burden due to the standardization of data and the streamlined process.

In compliance with the PRA, the information collection request (ICR) abstracted below was forwarded to OMB for review and comment. The ICR describes the nature of the information collection and its expected burden.

Title: Corporate Average Fuel Economy.

Type of Request: Reinstatement and amendment of a previously approved collection.

OMB Control Number: 2127-0019.

Form Numbers: NHTSA Form 1474 (CAFE Projections Reporting Template) and NHTSA Form 1475 (CAFE Credit Template).

Requested Expiration Date of Approval: Three years from date of approval.

Summary of the collection of information: As part of this rulemaking, NHTSA is reinstating and modifying its previously-approved collection for CAFE-related collections of information. NHTSA and EPA have coordinated their compliance and reporting requirements in an effort not to impose duplicative burdens on regulated entities. This information collection contains three different components: burden related to NHTSA's CAFE reporting requirements; burden related to CAFE compliance, but not via reporting requirements; and information gathered by NHTSA to help inform CAFE analyses. All templates referenced in this section will be available in the rulemaking docket.

1. CAFE Compliance Reports

NHTSA is reinstating[2167] its collection related to the reporting requirements in 49 U.S.C. 32907, "Reports and tests of manufacturers." In that section, manufacturers are statutorily

[2167] This collection expired on April 30, 2016.

required to submit CAFE compliance reports to the Secretary of Transportation.[2168] The reports must state if a manufacturer will comply with its applicable fuel economy standard(s), describe what actions the manufacturer intends to take to comply with the standard(s), and include other information as required by NHTSA. Manufacturers are required to submit two CAFE compliance reports—a pre-model year report (PMY) and a mid-model year (MMY) report—each year. In the event a manufacturer needs to correct previously-submitted information, a manufacturer may need to file additional reports.[2169]

To implement this statute, NHTSA issued 49 CFR part 537, "Automotive Fuel Economy Reports," which adds additional definition to the terms of section 32907. The first report, the PMY report must be submitted to NHTSA before December 31 of the calendar year prior to the corresponding model year and contain manufacturers' projected information for that upcoming model year. The second report, the MMY report must be submitted by July 31 of the given model year and contain updated information from manufacturers based on actual and projected information known midway through the model year. Finally, the last report, a supplementary report, is required to be submitted anytime a manufacturer needs to correct information previously submitted to NHTSA.

Compliance reports must include information on passenger and non-passenger automobiles (trucks) describing the projected and actual fuel economy standards, fuel economy performance values, production sales volumes and information on vehicle design features (*e.g.*, engine displacement and transmission class) and other vehicle attribute characteristics (*e.g.*, track width, wheel base, and other light truck off-road features). Manufacturers submit confidential and non-confidential versions of these reports to NHTSA. Confidential reports differ by including estimated or actual production sales information, which is withheld from public disclosure to protect each manufacturer's competitive sales strategies. NHTSA uses the reports as the basis for vehicle auditing and testing, which helps manufacturers correct reporting errors prior to the end of the model year and facilitate acceptance of their final CAFE report by the Environmental Protection Agency (EPA). The reports also help the agency, as well as the manufacturers who prepare them, anticipate potential compliance issues as early as possible, and help manufacturers plan their compliance strategies.

Further, NHTSA is modifying this collection to account for additional information manufacturers are required to include in their reports. In the CAFE standards previously promulgated for MY 2017 and beyond,[2170] NHTSA allowed for manufacturers to gain additional fuel economy benefits by installing certain technologies on their vehicles beginning with MY

[2168] 49 U.S.C. 32907 (delegated to the NHTSA Administrator at 49 CFR 1.95). Because of this delegation, for purposes of discussion, statutory references to the Secretary of Transportation in this section will be discussed in terms of NHTSA or the NHTSA Administrator.

[2169] Specifically, a manufacturer shall submit a report containing the information during the 30 days before the beginning of each model year, and during the 30 days beginning the 180th day of the model year. When a manufacturer decides that actions reported are not sufficient to ensure compliance with that standard, the manufacturer shall report additional actions it intends to take to comply with the standard and include a statement about whether those actions are sufficient to ensure compliance.

[2170] 77 FR 62623 (Oct. 15, 2012).

2017.[2171] These technologies include air-conditioning systems with increased efficiency, off-cycle technologies whose benefits are not adequately captured on the Federal Test Procedure and/or the Highway Fuel Economy Test,[2172] and hybrid electric technologies installed on full-size pickup trucks. Prior to MY 2017, manufacturers were unable to earn a fuel economy benefit for these technologies, so NHTSA's reporting requirements did not include an opportunity to report them. Now, manufacturers must provide information on these technologies in their CAFE reports. NHTSA requires manufacturers to provide detailed information on the model types using these technologies to gain fuel economy benefits. These details are necessary to facilitate NHTSA's technical analyses and to ensure the agency can perform random enforcement audits when necessary.

In addition to a list of all fuel consumption improvement technologies utilized in their fleet, 49 CFR 537 requires manufacturers to report the make, model type, compliance category, and production volume of each vehicle equipped with each technology and the associated fuel consumption improvement value (FCIV). NHTSA is adding the reporting and enforcement burden hours and cost for these new incentives to this collection. Manufacturers can also petition the EPA and NHTSA, in accordance with 40 CFR 86.1868-12 or 40 CFR 86.1869-12, to gain additional credits based upon the improved performance of any of the new incentivized technologies allowed for model year 2017. EPA approves these petitions in collaboration with NHTSA and any adjustments are taken into account for both programs. As a part the agencies' coordination, NHTSA provides EPA with an evaluation of each new technology to ensure its direct impact on fuel economy and an assessment on the suitability of each technology for use in increasing a manufacturer's fuel economy performance. Furthermore, at times, NHTSA may independently request additional information from a manufacturer to support its evaluations. This information along with any research conclusions shared with EPA and NHTSA in the petitions is required to be submitted in manufacturer's CAFE reports.

NHTSA is changing the burden hours for its CAFE reporting requirements in 49 CFR part 537. NHTSA is reducing the total amount of time spent collecting the required reporting information by standardizing the required data and streamlining the collection process using a standardized reporting template. The standardized template will be used by manufacturers to collect all the required CAFE information under 49 CFR 537.7(b) and (c) and provides a format which ensures accuracy, completeness, and better alignment with the final data provided to EPA.

2. Other CAFE Compliance Collections

NHTSA is adopting a new standardized template for manufacturers buying CAFE credits and for manufacturers submitting credit transactions in accordance with 49 CFR part 536. In 49 CFR part 536.5(d), NHTSA is required to assess compliance with fuel economy standards each year, utilizing the certified and reported CAFE data provided by the EPA for enforcement of the CAFE program pursuant to 49 U.S.C. 32904(e). Credit values are calculated based on the CAFE data from the EPA. If a manufacturer's vehicles in a particular compliance category performs

[2171] These technologies were not included in the burden for part 537 at the time as the additional reporting requirements would not take effect until years later.
[2172] *E.g.*, engine idle stop-start systems, active transmission warmup systems, etc.

better than its required fuel economy standard, NHTSA adds credits to the manufacturer's account for that compliance category. If a manufacturer's vehicles in a particular compliance category perform worse than the required fuel economy standard, NHTSA will add a credit deficit to the manufacturer's account and will provide written notification to the manufacturer concerning its failure to comply. The manufacturer will be required to confirm the shortfall and must either: submit a plan indicating how it will allocate existing credits or earn, transfer, and/or acquire credits or pay the equivalent civil peualty. The manufacturer must submit a plan or payment within 60 days of receiving notification from NHTSA.

Manufacturers should use the credit transaction template any time a credit transaction request is sent to NHTSA. For example, manufacturers that purchase credits and want to apply them to their credit accounts will use the credit transaction template. The template NHTSA is adopting is a simple spreadsheet that trading parties fill out. When completed, parties will be able to click a button on the spreadsheet to generate a joint transaction letter for the parties to sign and submit to NHTSA, along with the spreadsheet. NHTSA believes these changes will significantly reduce the burden on manufacturers in managing their CAFE credit accounts.

Finally, NHTSA is accounting for the additional burden due to existing CAFE program elements. In 49 CFR part 525, small volume manufacturers submit petitions to NHTSA for exemption from an applicable average fuel economy standard and to request to comply with a less stringent alternative average fuel economy standard. In 49 CFR part 534, manufacturers are required to submit information to NHTSA when establishing a corporate controlled relationship with another manufacturer. A controlled relationship exists between manufacturers that control, are controlled by, or are under common control with, one or more other manufacturers. Accordingly, manufacturers that have entered into written contracts transferring rights and responsibilities to other manufacturers in controlled relationships for CAFE purposes are required to provide reports to NHTSA. There are additional reporting requirements for manufacturers submitting carry back plans and when manufacturers split apart from controlled relationships and must designate how credits are to be allocated between the parties.[2173] Manufacturers with credit deficits at the end of the model year, can carry back future earned credits up to three model years in advance of the deficit to resolve a current shortfall. The carryback plan proving the existence of a manufacturer's future earned credits must be submitted and approved by NHTSA, pursuant to 49 U.S.C. 32903(b).

3. Analysis Fleet Composition

As discussed in Section [xxx], in setting CAFE standards, NHTSA creates an analysis fleet from which to model potential future economy improvements. To compose this fleet, the agency uses a mixture of compliance data and information from other sources to replicate more closely the fleet from a recent model year. While refining the analysis fleet, NHTSA occasionally asks manufacturers for information that is similar to information submitted as part of EPA's final model year report (*e.g.*, final model year vehicle volumes). Periodically, NHTSA may ask manufacturers for more detailed information than what is required for compliance (*e.g.*, what engines are shared across vehicle models). Often, NHTSA requests this information from

[2173] *See* 49 CFR part 536.

manufacturers after manufacturers have submitted their final model year reports to EPA, but before EPA processes and releases final model year reports.

Information like this, which is used to verify and supplement the data used to create the analysis fleet, is tremendously valuable to generating an accurate analysis fleet, and setting maximum feasible standards. The more accurate the analysis fleet is, the more accurate the modeling of what technologies could be applied will be. Therefore, NHTSA is accounting for the burden on manufacturers to provide the agency with this additional information. In almost all instances, manufacturers already have the information NHTSA seeks, but it might need to be reformatted or recompiled. Because of this, NHTSA believes the burden to provide this information will often be minimal.

Affected Public: Respondents are manufacturers of engines and vehicles within the North American Industry Classification System (NAICS) and use the coding structure as defined by NAICS including codes 33611, 336111, 336112, 33631, 33631, 33632, 336320, 33635, and 336350 for motor vehicle and parts manufacturing.

Respondent's obligation to respond: Regulated entities are required to respond to inquiries covered by this collection. 49 U.S.C. 32907. 49 CFR part 525, 534, 536, and 537.

Frequency of response: Variable, based on compliance obligation. Please see PRA supporting documentation in the docket for more detailed information.

Average burden time per response: Variable, based on compliance obligation. Please see PRA supporting documentation in the docket for more detailed information.

Number of respondents: 23.

4. Estimated Total Annual Burden Hours and Costs:

Table X-2 - Estimated Burden for Reporting Requirements

	Manufacturers		Government	
	Hours	Cost	Hours	Cost
Prior Collection	3,189.00	$24,573.50	975.00	$31,529.00
Current Collection	5,337.50	$266,326.83	3,038.00	$141,246.78
Difference	2,148.50	$241,753.33	2,023.00	$109,717.78

O. Privacy Act

In accordance with 5 U.S.C. 553(c), the agencies solicited comments from the public to inform the rulemaking process better. These comments are posted, without edit, to www.regulations.gov, as described in DOT's system of records notice, DOT/ALL-14 FDMS, accessible through www.transportation.gov/privacy. In order to facilitate comment tracking and response, the agencies encouraged commenters to provide their names, or the names of their organizations; however, submission of names is completely optional.

[Text Forthcoming]