Testimony of
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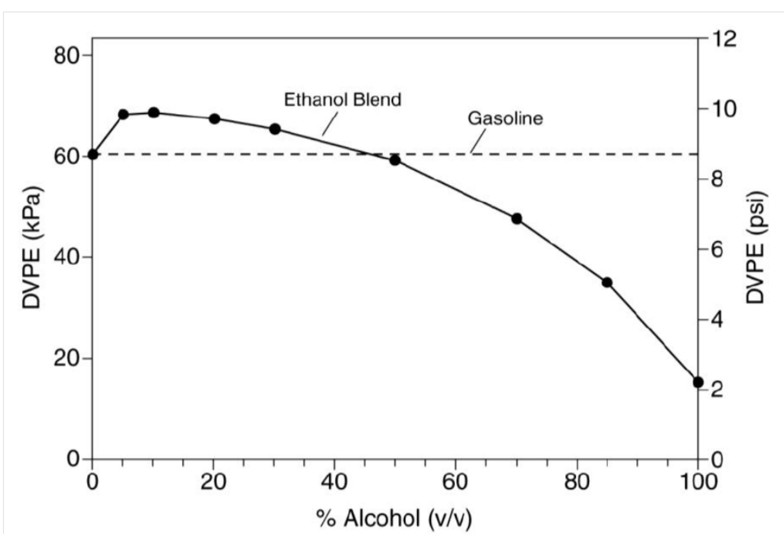
This testimony summarizes the air emission impacts of using E15 (fuel which is 15% ethanol, 85% petroleum based) in place of E10 (fuel which is 10% ethanol, 90% petroleum based). It is provided to the Senate Committee on Environment and Public Works so that they may assess the effects of Senate Bill, S.517, that would allow E15 to have the same 1 psi vapor pressure allowance or waiver currently permitted for E10 (see box next page on regulatory background). At this time virtually all of the fuel sold in the U.S. is E10 and extending the 1 psi waiver to higher ethanol fuels will encourage the use of E15 in place of E10.

This report focuses primarily on the pollutants which impact ground-level ozone, i.e. volatile organic compounds (VOCs) and nitrogen oxides (NOx).

Impact of Ethanol on Vapor Pressure. The addition of 10% ethanol to a base hydrocarbon blendstock results in a roughly 1 psi (6.9 kPa) increase in vapor pressure. The addition of 15% ethanol to the same blendstock results in almost exactly the same impact on the vapor pressure. Dry vapor pressure equivalent, or DVPE, is the modern equivalent of Reid vapor pressure, or RVP.



Fuel effects on motor vehicle emissions are difficult to quantify because different vehicles can behave quite differently. Nonetheless it can be concluded that replacing E10 with E15 that benefits from the same 1 psi waiver is a small change with minimal emissions impacts according to the best available emissions test data. On average, the total tailpipe organic emissions and the ozone forming potential of those organics will be expected to decrease or stay the same, and NOx is expected to be unchanged with a move to E15. Ethanol and acetaldehyde emissions will likely increase. Carbon monoxide will decrease.

This analysis is based on studies reported in the peer-reviewed scientific literature and by the coalition of petroleum and automobile companies that make up the Coordinating Research Council or CRC.

Perhaps the most applicable study was done in 2008 by a team comprised of scientists from three national laboratories.[1] They conducted emissions testing on 16 vehicles, model years ranging from 1999 through 2007 using E0, E10, E15 and E20. They found that increasing the ethanol content resulted in no significant effect on NOx or organic tailpipe emissions although the results varied widely among vehicles; CO emissions were reduced and ethanol and acetaldehyde emissions increased. Some of those results are shown in the figure below.

Regulatory Background. Ethanol and gasoline fuel mixtures are in common use in the United States with E10 (10% ethanol, 90% gasoline blendstock) comprising more than 90% of the retail fuel supply in recent years. In October 2010, the EPA expanded the use of ethanol by granting a waiver to allow the retail sale of concentrations of up to 15% ethanol in gasoline (E15) for use in light-duty on-highway vehicles model year 2007 and later. In January 2011, the waiver was expanded to allow the use of ethanol in older light-duty vehicles, model years 2001 to 2006.

When ethanol was first permitted as an additive in gasoline at concentrations of up to 10% in 1979, its effect on vapor pressure was not regulated. However, beginning with the implementation of the Clean Air Act Amendments of 1990, the United States Environmental Protection Agency (EPA) set the same maximum allowable RVP for both gasoline and gasoline/ethanol blends: for the summer high ozone season, 9.0 psi, with more stringent standards set for nonattainment areas. (The summertime high ozone season has been determined by the EPA to run from June 1 to September 15.)

However, only two years later, new EPA regulations (40 CFR 80.27) provided a 1-psi waiver for ethanol blends that contained between 9 and 10 percent ethanol. The purpose of the 1-psi waiver was to support the emerging ethanol industry. At that time EPA believed it would be difficult to economically justify a separate storage and distribution system for the small amount of lower vapor pressure gasoline needed for ethanol blending, with the result that low RVP fuel for ethanol blending would not be made available. The waiver allowed E10 to be made with the same gasoline distributed as fuel to be used without ethanol addition.

Today the 1 psi waiver is not available for E15. Because it is not, lower cost (i.e. higher DVPE) blendstock can be used with E10 than in E15 with the result that little E15 is marketed.

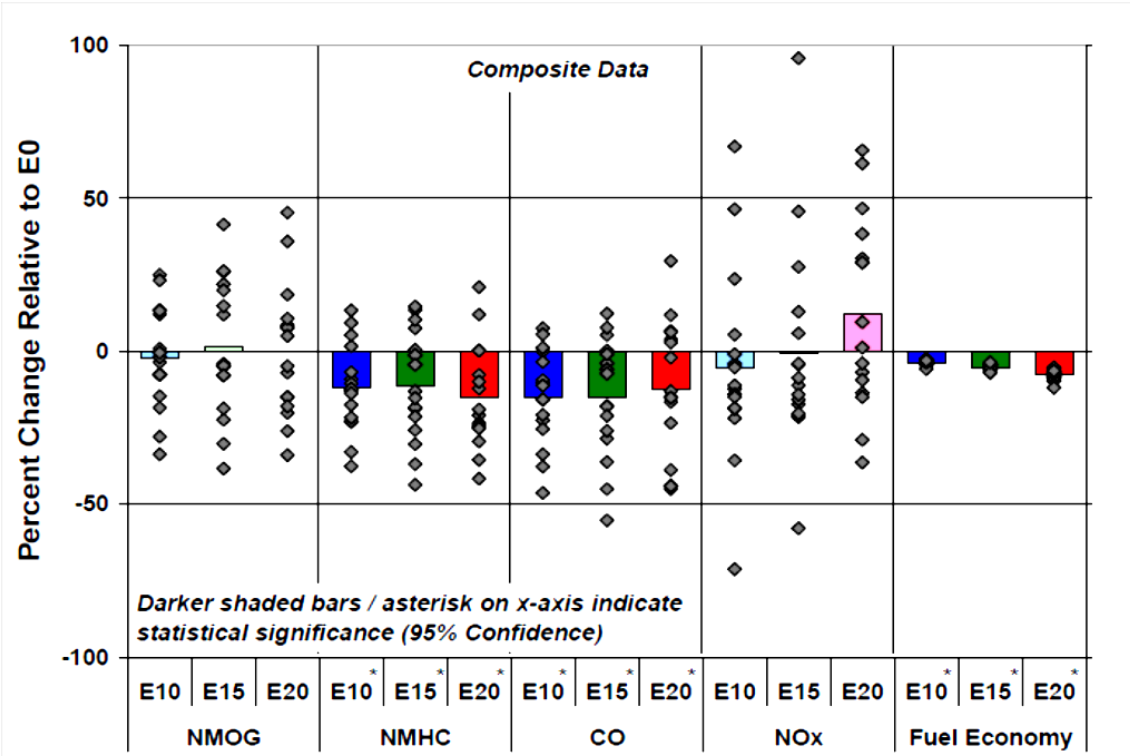


Figure 2. Percentage change in emissions from vehicles using different ethanol content fuels. [3] Diamonds are individual emissions measurements, bars are average emission results. NMOG = non-methane organic gas; NMHC = non-methane hydrocarbons.

Similar results on three post 2001 model year vehicles were reported by Karavalakis and his colleagues at UC Riverside (one of which was not tested on E15 but was tested on E20).[2,3] The CRC also reported that increased ethanol content up to 20% ethanol reduced CO emissions (based on testing of E0, E10 and E20), although the same study also reported an increase in NOx emissions with higher ethanol content.[4] Air Improvement Resources, Inc.[5] analyzed the results of the twelve 2001 and newer vehicles included in another DOE study[6] tested on E0, E10, E15 and E20 and found that non-methane hydrocarbons (NMHC), carbon monoxide and NOx trended slightly lower with higher ethanol contents. In another study conducted by a subcontractor to NREL, NMHC and carbon monoxide emissions were either equal or lower for six vehicles aged and then emissions tested on E15 versus E0, and NOx emissions were not statistically different.[7]

The total amount and composition of the organics emitted provides a rough gauge of the ozone forming potential of the emissions, as not all organics are equally prone to reacting to form ozone. Thus studies which considered the reactivity of the specific organics released are more accurate at determining the ozone forming potential of the emissions. The UC Riverside team did this analysis for emissions from two 2012 model year vehicles and found that the ozone reactivity for emissions from E15 were less than those for E10 as shown in the figure below.

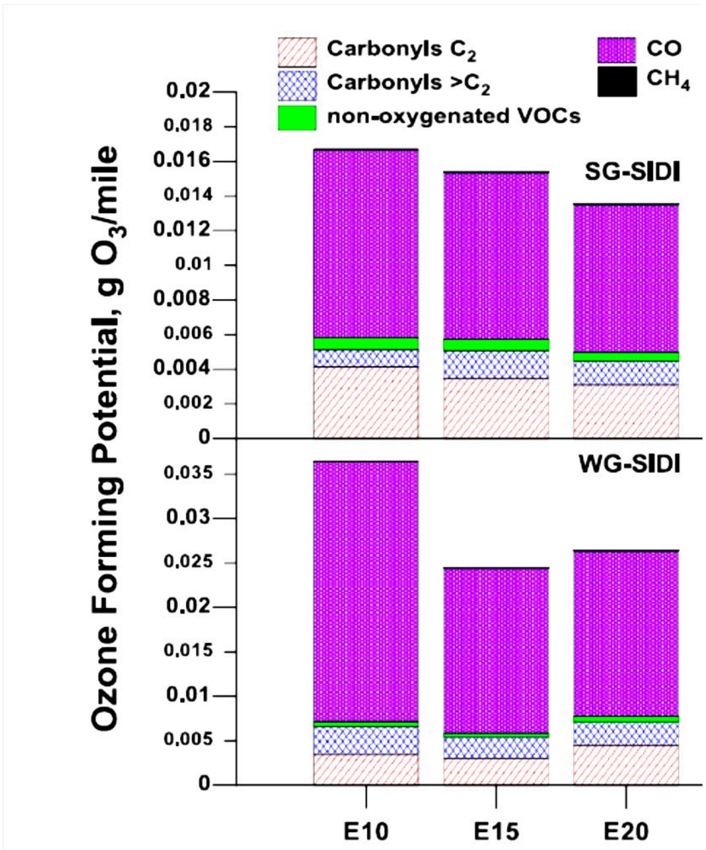


Figure 3. Ozone forming potential of exhaust from vehicles using different ethanol content fuels.[4]

Although, testing on flex-fuel vehicles may not be representative of non-flex-fuel vehicles, it does seem likely that changes in ethanol content would have the same effect on the relative proportion of different organics in the exhaust. For that reason, I also considered the results reported by the CRC in 2011. They found that the ozone forming potential of flex-fuel vehicles did not increase with increased ethanol content in the fuel and in one case decreased.[8]

In addition to tailpipe emissions, vehicles emit additional organic compounds to the atmosphere via evaporation or permeation. There have been no significant studies comparing evaporative emissions of E15 and E10. Two studies[9,10] made with E20 and E10 show mixed results, suggesting that increases in evaporative emissions between vehicles using E10 and E15 of the same vapor pressure are small or non-existent. In another study, limited data from the testing of four vehicles using E0 and E15 showed no significant differences between the two fuels.[11]

In conclusion, the available emissions test data indicates that replacing E10 with an E15 of the same vapor pressure will cause a slight decrease in emissions of ozone forming organic compounds and carbon monoxide, and no change in NOx.

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[2] Karavalakis, G., D. Short, D. Vu, R.L. Russell, A. Asa-Awuku, H. Jung, K.C. Johnson, T. D. Durbin, "The impact of ethanol and iso-butanol blends on gaseous and particulate emissions from two passenger cars equipped with spray-guided and wall-guided direct injection SI (spark ignition) engines, Energy, 82 (2015)168-179.
[3] Karavalakis, G., T.D. Durbin, M. Shrivastava, Z. Aheng, M. Villela, H. Jung, "Impacts of ethanol fuel level on emissions of regulated and unregulated pollutants from a fleet of gasoline light-duty vehicles," Fuel (3 (2012) 549-558.
[4] CRC E-74b, Effects of Vapor Pressure, Oxygen Content and Temperature on CO Exhaust Emissions, May 2009 https://crcao.org/reports/recentstudies2009/E-74b/E-74b%20Revised%20Final_Report_SR20090503.pdf, accessed June 9, 2017.
[5] Air Improvement Resources, Effects of E15 Ethanol Blends on HC, CO and NOx Regulated Emissions from On-Road 2001 and Later Model Year Motor Vehicles, July 15, 2011
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[10] CRC E 77-2, Enhanced Evaporative Emission Vehicles, March 2010, accessed June 9, 2017.
[11] Vertin, K., G. Glinsky, A. Reek, Comparative Emissions Testing of Vehicles Aged on E0, E15 and E20 Fuels, SGS Environmental Testing Corporation, Aurora, CO, NREL/SR-5400-55778.