TESTIMONY BY

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BEFORE
THE SENATE SUBCOMMITTEE
ON CLEAN AIR, CLIMATE CHANGE, AND NUCLEAR SAFETY

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Introduction

Mr. Chairman, my name is Tim Regan. I'm the President of the Emissions Control Technology Association ("ECTA"). I'm here to thank you today for taking the leadership on the diesel retrofit issue.

ECTA represents the companies that have been at the cutting edge of mobile source emissions control technology for three and a half decades. Our members invented and developed the core, specifically the substrate and the catalyst, of the catalytic converter.

They call our technology "aftertreatment" because it performs a chemical conversion or a filtering function to the emissions produced by the engine. In essence, the technology acts like a small chemical plant that neutralizes the nitrogen oxide ("NOx"), carbon monoxide ("CO"), and hydrocarbons ("HC") in gasoline exhaust. In the case of diesel engines, it goes one step further by burning the fine particulate matter ("$PM_{2.5}$").

Our technology has had a profound positive impact on the environment both here and abroad. Since 1975, the catalytic converter has removed 1.5 billion tons of pollution from American skies and 3 billion tons worldwide.[1] As the catalytic converter is the precursor to diesel retrofits technology, we are confident that similar profound results will be generated by the deployment of diesel retrofits.

In light of this confidence, we strongly support S.1265, the Diesel Emissions Reduction Act of 2005. It will accelerate deployment of diesel retrofit technology, which is good for human health and good for the economy. Obviously, these are two compelling reasons to support your bill.

[1] *See* Corning Press Release citing the Manufacturers of Emission Control Association ("MECA") (February 15, 2005), "< http://www.corning.com/environmentaltechnologies/media-center/press-releases/2005021501.aspx>.

Before I explain why we believe this to be the case, I'd like to tell you a little bit about our industry and our technology.

Industry and Technology

Your bill will accelerate the deployment of diesel emissions reduction technology on public fleets throughout the Nation. This technology covers engine rebuild, engine replacement, and exhaust aftertreatment, which is commonly referred to as diesel retrofits. My discussion today will focus on the diesel retrofit technology developed and produced by ECTA's members.

Diesel retrofit technology involves several levels of development and manufacture. First, a substrate material must be developed and manufactured to provide the foundation for the catalyst and to impart filtration. This substrate can consist of either a ceramic or a metal material. It can be used for a diesel oxidation catalyst ("DOC"), a diesel particulate filter ("DPF"), and a lean-NOx catalysts ("LNC") which can all be applied to diesel engines.

At a second level, the substrates are frequently coated by a catalyst manufacturer with a high-surface area material onto which a catalytic material is applied. These catalysts, combined with the exhaust heat absorbed by the substrate create a chemical reaction. In a diesel application, this chemical reaction converts harmful carbon monoxide, hydrocarbons, and particulate matter into harmless water and carbon dioxide. In the case of LNC, the chemical reaction converts nitrogen oxides to nitrogen and oxygen.

A DOC performs a catalytic reaction similar to that of an automotive catalytic converter. It is the most cost-effective diesel retrofit technology for removing up to 90% of the carbon monoxide, 60% to 90% of the hydrocarbons, and 20% to 50% of the particulate matter from diesel exhaust[2]. It costs approximately $400 to $1,000 per device depending on the application.[3]

[2] *See* Diesel Technology Forum, "Cleaner Air, Better Performance: Strategies for Upgrading and Modernizing Diesel Engines" (May 2003) <http://www.dieselforum.org/whitepaper/downloads/retrofit.pdf>, Figure 4, pg. 5.

A DPF is either coated with the catalytic material or not coated depending on the application. It is composed of a porous material which filters over 90% of the fine particulate matter from the diesel exhaust.[4] Diesel particulate matter takes the form of solid carbon particles and unspent fuel and lube oil. The DPF can be regenerated using the heat from the exhaust or auxiliary heat to burn the trapped particulates. If it is coated with the catalytic material, it also reduces carbon monoxide and hydrocarbons. Although more expensive than a DOC, a diesel particulate filter is very cost-effective because it addresses the primary threat to human health in diesel exhaust. It costs approximately $7,500 per device.[5]

Diesel retrofit technologies are elegant from an engineering point of view because they are passive in nature and require little, if any, maintenance. They occasionally need to be cleaned of ash that comes from the lube oil. These devices have been demonstrated to last over 450,000 miles in some retrofit applications.

At a third level, the diesel oxidization and the diesel particulate filter are secured in a metal canister which provides protection and durability. The canister is installed on the exhaust system of a diesel vehicle.

Diesel particulate filter systems will be required equipment under the EPA's 2007 Heavy Duty Diesel Rule ("2007 Rule") for on-road heavy duty vehicles produced in model year 2007 and beyond. Under regulations that will go into effect beginning in 2010, devices which are currently in development in our industry will reduce nitrogen oxide from diesel exhaust by more

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[3] *See* Manufacturers of Emission Control Association ("MECA"), "Retrofitting Emission Controls on Diesel-Powered Vehicles" (March 2002). <http://www.meca.org/jahia/Jahia/engineName/filemanager/pid/229/dieselretrofitwp.pdf?actionreq=actionFileDownload&fileItem=220>.

[4] *See supra footnote 2*.

than 90% from today's levels. These include nitrogen oxide traps, selective catalytic reduction, and other technologies.

Now I'd like to turn my attention to the reasons why we support your legislation.

Clean Air and Health Impact

Unfortunately, diesel engines have received a "bad rap". As they say, "my daddy's dirty diesel". And this may have been true 10 years ago because diesel engines produced comparatively higher levels of PM and NOx than gasoline-powered vehicles. But, substantial progress has been made in reducing diesel emissions over the last decade. Diesel engines manufactured today emit 83% less particulate matter and 63% less nitrogen oxide than they did in 1988.[5]

This is not to say that additional improvement cannot be made in diesel emissions. The new 2007 Diesel Rule will require even further reduction of particulate matter and nitrogen oxides. These new regulations will reduce both PM and NOx emission by 98% from their 1988 levels.[6]

These air quality improvements can significantly enhance human health. We measure these health effects by estimating the economic welfare associated with reduced levels of sickness and mortality risk arising from improved air quality. Studies have been done that estimate the health cost of diesel and other mobile source emissions.

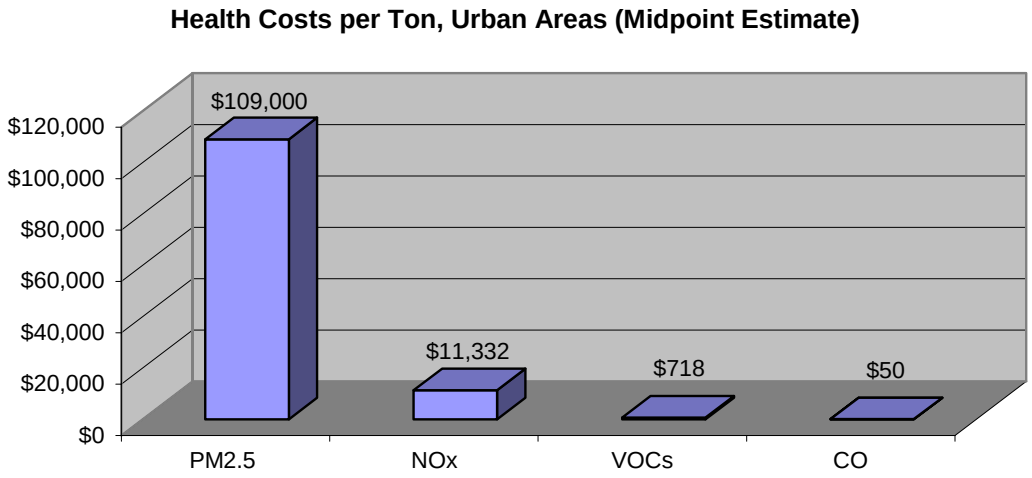
These estimates are extremely complex because they require estimating emissions generated by motor vehicles, estimating human exposure to air pollutants, relating these changes to physical health effects, and relating these health effects to changes in economic welfare. Essentially, we must estimate the value of illness and mortality risk.

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[5] *See supra footnote 2, p. 1.*
[6] *Id.*

While the absolute levels of these estimates are clearly open to challenge, there is a broad consensus that diesel emissions cause or aggravate respiratory problems and chronic bronchial conditions such as asthma. In diesel exhaust, particulate matter measured below the 2.5 micron level is particularly troublesome as a matter of human health. As indicated in Figure 1 below, the health effects of $PM_{2.5}$ have been measured as high as $109,000 per ton compared to $11,332 per ton for NOx, $718 per ton for volatile organic compounds, and $50 per ton for carbon monoxide. In order words, $PM_{2.5}$ is over 2000 times more harmful than carbon monoxide.

Figure 1



Source: McCubbin, Donald and Mark Delucchi, Journal of Transport Economics and Policy, "The Health Costs of Motor-Vehicle-Related Air Pollution" (September 1999).

Using these tools, EPA has estimated the health benefits of diesel emission reduction technology to be quite significant. For example, EPA estimates that the 2007 Rule will generate $66 billion in health benefits annually when the new vehicles have significantly penetrated the fleet after the year 2020.[7] This equates to about one half of one percent of the entire U.S.

[7] *See* Environmental Protection Agency, (July 7, 2005) "2007 Heavy-Duty Highway Final Rule" <http://www.epa.gov/OMSWWW/diesel.htm>

economy in 2005. This is pretty significant when you consider the fact that a three percentage point growth in the economy is believed to be quite robust.

These health effects are generated under the 2007 Rule by the deployment of diesel emission technology on new vehicles. The Rule does nothing to reduce emissions from the existing 11 million diesel-powered vehicles on the road today.[8] Because diesels are so durable, existing vehicles in the fleet will not be fully replaced until 2030.[9] Hence, the need for diesel retrofits to reduce emissions on in-use vehicles during the balance of their useful life. The accelerated deployment of this technology on existing vehicles as authorized by S.1265 will realize tremendous health benefits in the short and medium term.

This reality is starkly reflected in the President's FY06 budget proposal for a new Clean Diesel Initiative to finance demonstration projects for diesel retrofit technology. This small investment is estimated in the President's budget to generate $360 million in health benefits.[10] We hope the Congress will appropriate the funds for this new program.

Most importantly, significant health benefits will be generated from the full implementation and funding of S.1265. As the Committee is well aware, EPA estimates that $1.5 billion investment in diesel retrofits generated by S.1265 will reduce diesel particulate matter pollution by 70,000 tons and generate over $20 billion in health benefits.[11]

It is particularly important that we capture these benefits today because so much of the Nation is currently exceeding national air quality standards for $PM_{2.5}$ as well as other criteria pollutants. EPA estimates that nearly 100 million people in the country reside in non-attainment

[8] *See* Senator Voinovich Press Release (June 16, 2005) <http://voinovich.senate.gov/news_center/record.cfm?id=238996&>
[9] *Id.*
[10] *See* Environmental Protection Agency, "The Budget for Fiscal Year for 2006", pg. 289.
[11] *See supra footnote 8.*

areas for fine particulate matter.[12] Since mobile source emissions account for 15% of all fine particulate matter pollution in the country and such pollution is deemed most threatening of the criteria pollutants[13], the accelerated deployment of diesel retrofit technology will contribute significantly toward achieving attainment and enhancing human health.

Economic Impact

In addition to the important health effects associated with S.1265, the bill also will have a very positive impact on the economy in several ways. First, it will accelerate deployment of diesel retrofit technology which has proven to be a very cost-effective means for achieving air quality improvement.

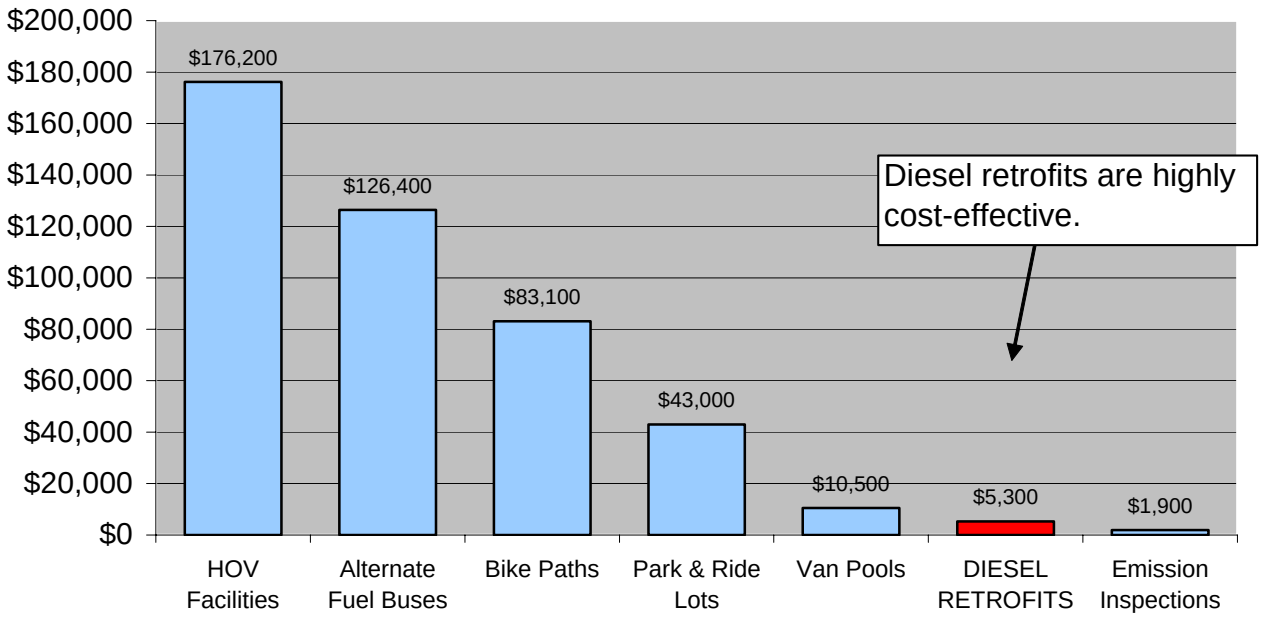
As indicated in Figure 2 below, we estimate that diesel retrofit technology is one of the most cost-effective means for improving air quality compared to other methods used under our interstate highway transportation statutes.

[12] *See* Environmental Protection Agency, AirData (November 2004) <http://www.epa.gov/air/data/nonat.html?us~usa~United%20States>.

[13] *See* Transportation Research Board of the National Academies' National Research Council , (April 2002) "The Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience", Figure 2-1, pg.44.

Figure 2

Median Cost per Ton Equivalent of Air Pollution Removed



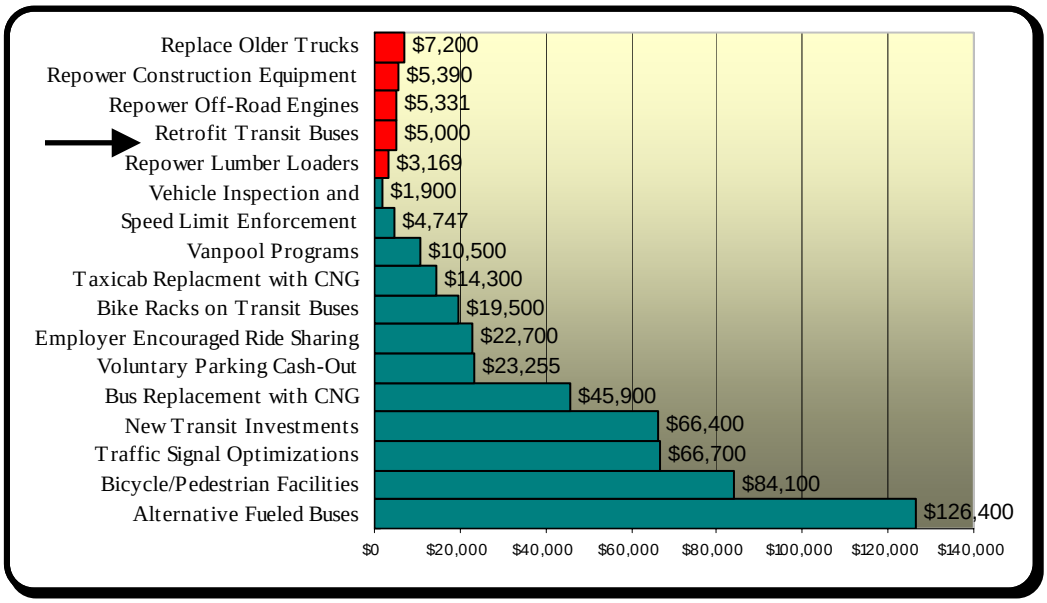
Source: Robert F. Wescott, "Cleaning the Air: Comparing the Cost Effectiveness of Diesel Retrofits vs. Current CMAQ Projects", (May 11, 2005).

These estimates show that diesel retrofits cost at most a mere $5,300 per ton of pollution reduction compared to a mid-point estimate of $126,400 for an alternative fuel bus. Only emission inspection and maintenance at a mid-point estimate of $1,900 per ton beats diesel retrofits. The analysis that supports these estimates is attached as Exhibit 1 for the Committee's convenience.

As indicated in Figure 3, our estimates are verified by analysis done by the Diesel Technology Forum which estimate diesel retrofits at about $5,000 per ton of emission reduction.

Figure 3

Dollars per Ton of NOx Reduction



Source: Diesel Technology Forum, "Cleaner Air, Better Performance: Strategies for Upgrading and Modernizing Diesel Engines"(May 2003)<http://www.dieselforum.org/whitepaper/downloads/retrofit.pdf>.

The second economic benefit associated with the deployment of diesel retrofits is reflected by the extremely favorable cost benefit associated with the investment. As I indicated above, the President's budget proposal reflects a $360 million return on a $15 million investment under the new Clean Diesel Initiative.[14] This is a 24 to 1 benefit-cost ratio. As the Members of the Committee are well aware, EPA further estimates that the cost-benefit ratio for S.1265 is 13 to 1.[15]

[14] *See supra footnote 11.*
[15] *See supra footnote 8.*

The third economic benefit is the investment that has been generated by the members of the Emissions Control Technology Association and others in the industry. It is estimated that our industry is investing over $1.8 billion to optimize and commercialize advanced diesel emission technologies to meet the requirements of existing EPA regulations and retrofits.[16]

This investment will generate good-paying manufacturing jobs in the United States. For example, Corning Incorporated, a leading manufacturer of ceramic substrates for diesel oxidization catalysts and diesel particulate filters, plans to invest over $350 million in research, development, and manufacturing and to generate over 300 new high-paying jobs in manufacturing.[17] This is important job creation in Western New York that is sorely in need of new economic growth.

Finally, new diesel emissions reduction technology generates growth through exports. The United States leads the world in mobile source emission reduction technology. As such, we are exporting catalytic converters, diesel oxidization catalysts and diesel particulate filters around the world, including China.

Conclusion

Mr. Chairman, in closing, I'd like to congratulate you again on your leadership. The prompt enactment and funding of S.1265 is good for human health and good for the economy for all the reasons that I have described. On behalf of the ECTA members, I can assure you that we will do everything in our power to help achieve enactment and funding.

[16] *See* MECA press release, (March 16, 2004), "Motor Vehicle Emission Controls Industry Continues to Make Necessary Investments to help meet EPA's 2007 and Later On-Road HDDE Standards".
[17] Interviews with Corning executives.

ILLUSTRATION 1

Substrate for Diesel Particulate Filter

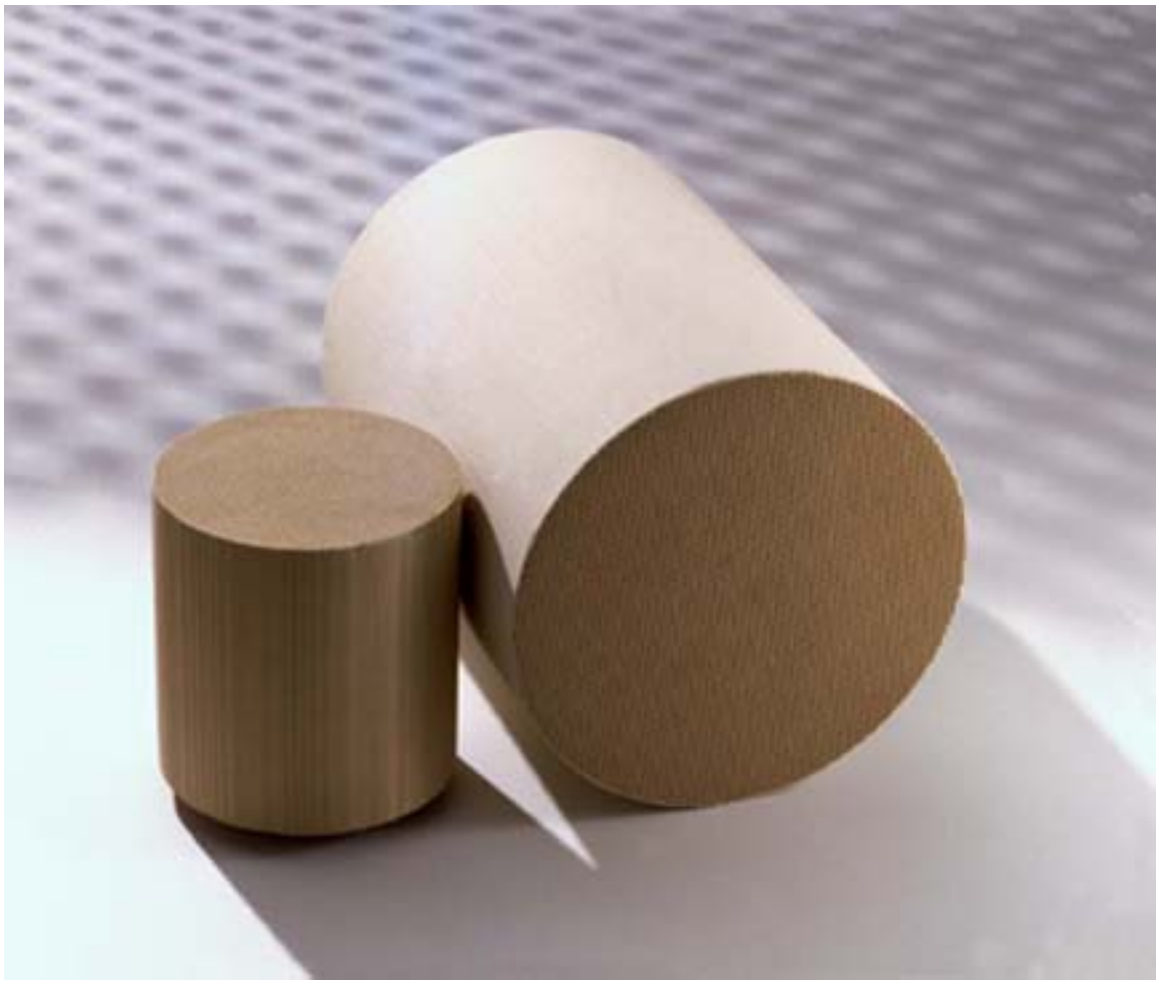


ILLUSTRATION 2

Substrate for Diesel Oxidation Catalyst



ILLUSTRATION 3

One day's soot from bus *without* filter



Exhibit 1

Cleaning the Air:
Comparing the Cost Effectiveness of
Diesel Retrofits vs. Current CMAQ Projects

An Analysis Prepared for the Emission Control Technology Association

by Robert F. Wescott, Ph.D.
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Washington, DC

May 11, 2005

Robert F. Wescott, Ph.D. is a Washington, DC-based economic consultant with 25 years of professional experience working on macroeconomic and industry/public policy issues. Dr. Wescott served as Special Assistant to the President for Economic Policy at the White House and as Chief Economist at the President's Council of Economic Advisers. From 1982-93 he was Chief Economist at Wharton Econometrics (WEFA Group), the private economic analysis firm, where he oversaw all economic modeling, forecasting, and consulting operations. Dr. Wescott also was an official in the Research Department of the International Monetary Fund where he did research on global economic risks and policy challenges. In 1990 he was research director at the International Center for the Study of East Asian Development in Kitakyushu, Japan. He holds a Ph.D. in Economics from the University of Pennsylvania, 1983.

Cleaning the Air:
Comparing the Cost Effectiveness of
Diesel Retrofits vs. Current CMAQ Projects

Executive Summary

- A key goal of U.S. air pollution programs, including the Congestion Mitigation and Air Quality (CMAQ) program created in 1990, has been to clean the air in cities to improve public health and lower medical costs. But while the CMAQ program has emphasized reductions of carbon monoxide, hydrocarbons, and ozone, recent research finds that the top air pollution problem in urban areas today is fine particulate matter, which is particles with a diameter of 2.5 micrometers or less ($PM_{2.5)}$.

- This pollutant, $PM_{2.5,}$ is a primary airborne threat to human health today costing more than $100,000 per ton in health costs. Researchers estimate that $PM_{2.5}$ is two to twenty times as harmful to human health as nitrous oxide, more than one hundred times as dangerous as ozone, and 2000 times as dangerous as carbon monoxide on a per ton basis.

- Diesel engine exhaust is a source of $PM_{2.5}$ emissions in urban areas. Approximately one third of these diesel emissions are due to on-road vehicles and about two thirds are due to off-road equipment, such as construction equipment.

- Diesel retrofit technology is currently available that is highly effective at reducing $PM_{2.5}$ emissions. Diesel oxidation catalysts (DOCs) are well suited for retrofitting older off-road vehicles and diesel particulate filters (DPFs) are highly efficient at reducing these pollutants where new low sulfur diesel fuels are available, as is already the case in most urban areas.

- From the point of view of cost effectiveness, diesel retrofits are superior to almost all current CMAQ strategies, including ride-share programs, van-pool arrangements, HOV lanes, traffic signalization, bike paths, and all strategies that attempt to modify behavior (like encouraging telecommuting.) Most of these CMAQ strategies cost $20,000 to $100,000 per ton equivalent of pollutant removed, and some cost as much as $250,000 per ton removed.

- Under conservative assumptions, diesel retrofits cost only $5,340 per ton equivalent of pollutant removed, In fact, among all CMAQ strategies, only emission inspection programs appear to exceed the cost effectiveness of diesel retrofits.

- Expanding the range of CMAQ projects to include diesel retrofits for construction equipment and off-road machinery in urban areas could be a highly effective way to spend public monies. More than 100 million Americans live in areas of the country where $PM_{2.5}$ levels exceed the EPA's guidelines.

Background

Cleaning the air to improve human health and lower medical costs has been an objective of U.S. government policy since at least the Clean Air Act of 1970. Concerns about poor air quality, especially in urban areas, led to the creation of the Congestion Mitigation and Air Quality (CMAQ) Program in 1990, which has set aside a portion of transportation monies for the past 15 years to fund innovative projects to reduce carbon monoxide, hydrocarbons, nitrous oxides, and smog in so-called non-attainment areas.[18] Vehicle emission inspection programs, high-occupancy vehicle (HOV) travel lanes, van pool programs, park-and-ride lots, and bike paths are examples of CMAQ projects.

There has been significant progress in the past 35 years in reducing carbon monoxide and hydrocarbon emissions and smog. Scientists, however, have been able to identify new airborne health risks whose costs are now becoming more fully appreciated. Notably, particulate matter (PM) has been found to have especially pernicious health effects in urban areas. Increasingly it is becoming understood that diesel engine emissions in urban areas, both from on-road trucks and buses and from off-road construction and other equipment, are a significant source of fine particulate matter pollution. This leads to a number of questions:

- What is the current assessment of the top health risks from air pollution from mobile sources in urban areas?
- What is the role of emissions from diesel engines?
- How does diesel retrofit technology to clean engine emissions after combustion compare with current CMAQ projects in terms of cost effectiveness?
- Are CMAQ funds currently being deployed in the most cost effective manner possible?

This paper examines these questions by reviewing the recent scientific, environmental, economic, and health policy literature.

The Health Costs of Air Pollution

In the 1960s and 1970s the key health risks from air pollution were deemed to come from carbon monoxide, hydrocarbons (or volatile organic compounds, VOCs), nitrous oxides (NO_x), and smog, and early clean air legislation naturally targeted these pollutants.[19] During the past ten years or so, however, researchers have identified new pollutants from mobile sources that have particularly harmful health effects, especially in urban areas. Top concern today centers around particulate matter, and especially on fine particulate matter. Fine particulates, with a diameter of less than 2.5 micrometers ($PM_{2.5}$), can get trapped in the lungs and can cause a variety of respiratory ailments similar to those caused by coal dust in coal miners. A significant portion of $PM_{2.5}$ emissions in urban areas come from off-road diesel equipment. According to analysis by

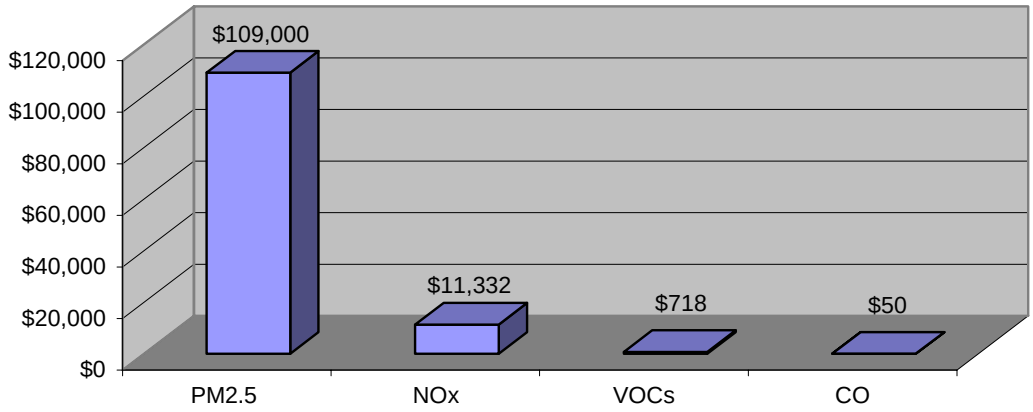
[18] The EPA has formal criteria for the definition of non-attainment areas, but generally these are the large U.S. cities.
[19] Catalytic converters installed on all cars since the mid 1970s, for example, have targeted these pollutants.

the California Air Resources Board, on-road engines account for about 27% of PM emissions in California and off-road equipment is responsible for about 66% of PM emissions.[20]

Analysis by Donald McCubbin and Mark Delucchi published in the *Journal of Transport Economics and Policy* evaluates the health costs of a kilogram of various air pollutants, including CO, NO_x, $PM_{2.5}$, sulfur oxides (SO_x), and VOCs.[21] These researchers estimate health costs from such factors as, hospitalization, chronic illness, asthma attacks, and loss work days for the U.S. as a whole, for urban areas, and for the Los Angeles basin. For urban areas, they find the range of health costs per kilogram of CO was from $0.01 to $0.10, NO_x was from $1.59 to $23.34, $PM_{2.5}$ was from $14.81 to $225.36, SO_x was from $9.62 to $90.94, and VOCs was from $0.13 to $1.45. Taking the mid-points of these estimates, a kilogram of $PM_{2.5}$ therefore was nearly 10 times more costly from a health point of view than a kilogram of NO_x, more than 150 times more costly than a kilogram of VOCs, and more than 2000 times more costly than a kilogram of CO. On a per ton basis, a ton of $PM_{2.5}$ causes $109,000 of health costs, a ton of NO_x costs $11,332, a ton of VOCs costs $718, and a ton of CO costs $50 (Chart 1).

Chart 1

Health Costs per Ton, Urban Areas (Midpoint Estimate)



Source: McCubbin and Delucchi (1999)

Effectiveness of Diesel Retrofit Filters

Given the high health costs of $PM_{2.5}$, significant effort has gone into the development of technological solutions to deal with the problem. The best technologies involve the use of post-combustion filters with a catalyzing agent, which together trap and break down dangerous

[20] *Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles*, California EPA Air Resources Board, October 2000, p. 1.
[21] McCubbin, Donald and Mark Delucchi (1999), The Health Costs of Motor-Vehicle-Related Air Pollution, *Journal of Transport Economics and Policy*, September, Vol. 33, Part 3, pp. 253-86.

pollutants before they are emitted into the air. All new diesel trucks will be required to use these technologies by 2007 according to U.S. EPA rules, and off-road equipment will have to use these technologies by 2010. (Rules require 95% reductions in emissions of several pollutants, as well as a 97% cut in the sulfur levels in diesel fuel.)[22] However, given that the lifespan of a diesel engine can be 20-30 years, it will take decades to completely turn over America's diesel fleet. Therefore, by lowering emissions from older diesels, retrofits are an effective path to cleaner air over the next few decades.

Diesel retrofit filters are highly effective at their chief function: preventing dangerous pollutants from ever entering the air. Diesel oxidation catalysts (DOCs), at $1,000 to $1,200 per retrofit, reduce PM by about 30% and can work with current higher sulfur diesel fuels. This yields a large benefit when installed on older, higher-polluting vehicles. In addition to their PM reducing capabilities, these filters also can cut the emission of carbon monoxide and volatile hydrocarbons by more than 70%.

Diesel particulate filters (DPFs), which generally cost $4,000-$7,000 per engine, are far more efficient. They are specifically targeted at keeping more dangerous PM out of the air than are DOCs. In fact, they can reduce $PM_{2.5}$ pollution from each vehicle by more than 90%, yielding an enormous cut in emissions over the life of the diesel engine, even when installed on newer, cleaner diesel vehicles. An additional requirement of DPFs, however, is that the vehicle must run on newer very low sulfur fuels. High sulfur fuel leads to sulfate emissions from the filter due to the very active catalysts needed to make the filters function properly. Thus, DPFs are most effective as a solution for vehicles in urban areas—such as construction equipment and urban fleets—where very low sulfur fuels are already available.[23]

These technologies are not new or experimental; they are already in use around the world. There are 2 million of these two technologies already at work in heavy-duty diesel vehicles worldwide. Further, there are 36 million DOCs and 2 million DPFs in use on passenger vehicles in Europe alone, where these technologies are currently being used, reaping cost-effective health benefits over the long term.

The CMAQ Program

The CMAQ program is the only federally funded transportation program chiefly aimed at reducing air pollution.[24] Its historical purpose has been twofold: to reduce traffic congestion and to fund programs that clean up the air Americans breath. Within its air quality mission, it is designed primarily to help non-attainment areas (mainly polluted urban zones) reach attainment for air quality standards under the Clean Air Act.[25] Historically many CMAQ projects have tried to change travel and traffic behavior in order to achieve its goals. These transportation control measures (TCMs) have been designed both to reduce traffic congestion as well as improve air

[22] "EPA Dramatically Reduces Pollution from Heavy-Duty Trucks and Buses, Cuts Sulfur Levels in Diesel Fuel," *Environmental News*, EPA, 12/21/00
[23] Very low sulfur diesel fuel will be available nationwide by 2006.
[24] Transportation Research Board of the National Research Council: *The Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience* (2002) p.1.
[25] ibid, p.1

quality. An example is a bicycle path. Designed to reduce the number of drivers on the road, bike paths could, in theory, achieve both goals. Further examples are vanpools, ridesharing and park and ride programs, and HOV lanes: all current CMAQ projects. Other projects have addressed emission reductions directly, as for example, through funding for state automobile emission inspection programs.

As a condition for reauthorizing the CMAQ program in 1998, the U.S. Congress required that a detailed 10-year assessment of the program be conducted. This review was performed by the Transportation Research Board of the National Research Council and was completed in 2002. This review found that CMAQ has been less than successful in reducing congestion and suggested that the most beneficial way for CMAQ to use its funds is to focus on air quality.[26] It also found that TCMs were less cost effective than measures to directly reduce emissions, such as through inspection programs.

Furthermore, the study suggested that CMAQ's focus within the domain of air quality is misplaced. CMAQ programs have targeted the gases considered the most dangerous pollutants for many years, like hydrocarbons, carbon monoxide, and nitrous oxides. While these gases pose recognized health and environmental risks, recent work has shown that the dangers of these substances pale in comparison to the danger of fine particulate matter.[27] In the words of the study, "Much remains to be done to reduce diesel emissions, especially particulates, and this could well become a more important focus area for the CMAQ program."[28] Further, discussing the fact that diesel-related CMAQ programs could be the most cost-effective, the study states, "had data been available on particulate reductions… the ranking of strategies focused on particulate emissions… would likely have shown more promising cost-effectiveness results."[29]

Comparing the Cost Effectiveness of Diesel Retrofits with Other CMAQ Projects

Given that $PM_{2.5}$ emissions from diesel engines are a leading health concern, that effective technology exists today to clean the emissions of off-road diesel equipment used extensively in the middle of American cities (non-attainment areas), and that the CMAQ 10-year review highlights the possible use of CMAQ funds for diesel retrofit projects, it is logical to compare the cost effectiveness of these diesel retrofits with current CMAQ projects. *The CMAQ Program: Assessing 10 Years Experience* (2002) estimates the median cost per ton of pollutant removed for 19 different CMAQ strategies and these estimates provide the comparison base. Published estimates for diesel retrofits are compared with these estimates.

As a first step in comparing the cost effectiveness of pollution reduction strategies, it must be noted that the CMAQ cost effectiveness estimates are presented as "cost per ton equivalent removed from air," with weights of 1 for VOCs, 4 for NO_x, but 0 for $PM_{2.5}$.[30] Relying upon the

[26] ibid, p.13
[27] ibid, p.13
[28] ibid, p.74
[29] ibid, p.131
[30] Importantly, the study's $PM_{2.5}$ weight of 0 does not reflect $PM_{2.5}$'s health costs, but rather that fact that standards have not yet been set for it by the U.S. EPA. As the CMAQ 10-year review says, "$PM_{2.5}$ is generally regarded as the pollutant with the most pernicious health consequences, though to date standards have not been promulgated for its regulation for both measurement and economic reasons." (p. 295).

McCubbin and Delucchi health cost estimates, however, even weighted NO_x should be considered more damaging than VOCs. That is, even though 0.25 ton (the 1:4 ratio above) of NO_x removed counts as the CMAQ equivalent of one ton of pollution removed, it has a higher health cost than a ton of VOCs ($11,332 / 4 = $2,883 for NO_x vs. $718 for VOCs). As a second step, conservatively assume that all CMAQ projects remove the more damaging pollutant (NO_x). This still means that a ton of $PM_{2.5}$ reduction would be worth at least 9.45 tons of regular CMAQ reductions ($109,000 for $PM_{2.5}$ / $11,332 for NO_x).

Diesel retrofits are estimated to cost $50,460 per ton of $PM_{2.5}$ removed by the California Air Resources Board (CARB).[31] This estimate is very conservative and substantially higher than that cited by industry sources. Using the CARB cost estimate, diesel retrofits cost $5,340 per ton equivalent of air pollution removed ($50,460 / 9.45), based upon the CMAQ definition of ton equivalent and on the conservative assumption that CMAQ projects remove the most damaging pollutant reviewed. If a less conservative and more realistic assumption is used – that CMAQ projects remove a mix of NO_x and VOCs – then the cost-effectiveness of diesel retrofits becomes substantially more favorable, and could be as low as $332 per ton of CMAQ pollutant removed.

This analysis means that diesel retrofits for construction equipment are highly cost effective when compared with current CMAQ strategies. As shown in Table 1 and Chart 2, some CMAQ strategies cost more than $250,000 per ton of pollutant removed (teleworking), and many are in the $20,000 to $100,000 per ton range (traffic signalization, park and ride lots, bike paths, new vehicles, etc.). The only current CMAQ project category that exceeds the cost effectiveness of diesel retrofits is emission inspection programs.

Other studies also conclude that diesel retrofits are highly cost effective compared with current CMAQ projects. The Diesel Technology Forum compared the benefits and costs of CMAQ projects with diesel retrofits for transit buses (for NO_x pollution reduction) and concluded that retrofits are a better use for CMAQ funds than any other typical CMAQ project, with the exception of inspection and maintenance programs and speed limit enforcement.[32] Also, the California EPA's Air Resources Board has estimated that diesel retrofits have a benefit of between $10 and $20 for each $1 of cost.[33] And the U.S. EPA, in its justification for new on-road diesel rules in 2007 and off-road rules in 2010 estimates the benefits for diesel particulate filters at roughly $24 for each $1 of cost.[34]

Table 1: Cost-Effectiveness of Current CMAQ Strategies
And Diesel Retrofits
(Median cost per ton equivalent of air pollution removed)

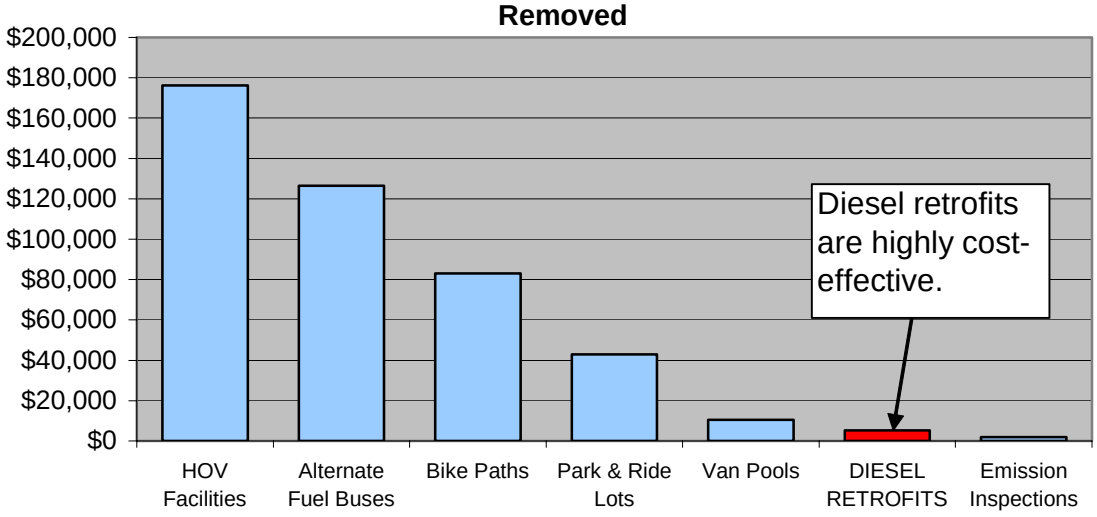
	Median Cost	Rank

[31] California Air Resources Board, "Staff Analysis of PM Emission Reductions and Cost-Effectiveness," Sept. 6, 2002.
[32] "The Benefits of Diesel Retrofits," Diesel Technology Forum. See http://dieselforum.org/retrofit/why_ben.html.
[33] "Perspectives on California's Diesel Retrofit Program," California EPA, Air Resources Board, presentation by C. Witherspoon, June 3, 2004.
[34] See, for example, "2007 Heavy-Duty Highway Final Rule," U.S. EPA, May 2000, which can be found at http://www.epa.gov/otaq/diesel.htm.

Inspection and Maintenance	$1,900	1
DIESEL RETROFITS	**$5,340**	**2**
Regional Rideshares	$7,400	3
Charges and Fees	$10,300	4
Van Pool Programs	$10,500	5
Misc. Travel Demand Management	$12,500	6
Conventional Fuel Bus Replacement	$16,100	7
Alternative Fuel Vehicles	$17,800	8
Traffic Signalization	$20,100	9
Employer Trip Reduction	$22,700	10
Conventional Service Upgrades	$24,600	11
Park and Ride Lots	$43,000	12
Modal Subsidies and Vouchers	$46,600	13
New Transit Capital Systems/Vehicles	$66,400	14
Bike/Pedestrian	$84,100	15
Shuttles/Feeders/Paratransit	$87,500	16
Freeway Management	$102,400	17
Alternative Fuel Buses	$126,400	18
HOV Facilities	$176,200	19
Telework	$251,800	20

Source: All costs from *The CMAQ Improvement Program: Assessing 10 Years of Experience, (2002)*, except diesel retrofit costs, which are from author's calculations.

Chart 2: Median Cost per Ton Equivalent of Air Pollution Removed



Conclusions

The top air pollution problem in U.S. urban areas today is almost certainly $PM_{2.5}$, which is estimated to cost more than $100,000 per ton in health costs. A major source of $PM_{2.5}$ emissions in urban areas is diesel engine exhaust. Approximately one third of these diesel emissions are due to on-road vehicles and about two thirds are due to off-road equipment. Off-road equipment in urban areas is a particular problem, because it gives off exhaust at ground level,frequently near large groups of people.

Diesel retrofit technology is currently available that is highly effective at reducing $PM_{2.5}$ emissions. DOCs are well suited for retrofitting older off-road vehicles and DPFs are highly efficient at reducing these pollutants where new low sulfur diesel fuels are available, as is already the case in most urban areas.

From a cost effectiveness point of view, diesel retrofits are superior to almost all current CMAQ strategies, including ride-share programs, van-pool arrangements, HOV lanes, traffic signalization, bike paths, and all strategies that attempt to modify behavior (like encouraging teleworking.) Only emission inspection programs exceed the cost effectiveness of diesel retrofits based upon conservative assumptions. Expanding the range of CMAQ projects to include diesel retrofits for construction equipment and off-road machinery in urban areas could be a highly effective way to spend public monies.

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