The Cost-Effectiveness of Heavy-Duty Diesel Retrofits and Other Mobile Source Emission Reduction Projects and Programs

United States
Environmental Protection
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Transportation and Regional Programs Division
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Introduction

The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) was enacted August 10, 2005, as Public Law 109-59. SAFETEA-LU creates new opportunities as well as responsibilities for States, Metropolitan Planning Organizations (MPOs), and other agencies involved in the selection of projects funded through the Congestion Mitigation and Air Quality Improvement Program (CMAQ). Among the changes, Section 1808 of SAFETEA-LU, for the first time, makes CMAQ funding available for many nonroad diesel retrofits for nonroad vehicles, engines, and construction equipment that are used on Title 23 projects in certain nonattainment areas. While acknowledging State and MPO roles and authority for making final project selections, Section 1808 also addresses funding priority. "(A) IN GENERAL – States and metropolitan planning organizations shall give priority in distributing funds received for congestion mitigation and air quality projects and programs from apportionments derived from applications of sections 104(b)(2)(B) and 104(b)(2)(C) to – (i) diesel retrofits, particularly where necessary to facilitate contract compliance, and other cost-effective emission reduction activities, taking into consideration air quality and health effects; and (ii) cost-effective congestion mitigation activities that provide air quality benefits. (B) SAVINGS – This paragraph is not intended to disturb the existing authorities and roles of governmental agencies in making final project selections."

To support the implementation of Section 1808, Congress included a provision for the EPA, in consultation with DOT, to publish information on diesel retrofit technologies that have been: 1) certified or verified by EPA or the California Air Resources Board (CARB)[1]; 2) identified by EPA or CARB as having an application and approvable test plan for verification; and 3) other available information regarding the emission reduction effectiveness and cost-effectiveness of diesel emission control technologies, taking into consideration air quality and health effects.[2]

In addition, The Energy Policy Act of 2005 (EPACT), enacted as Public Law 109-58 includes a Diesel Emissions Reduction Program that authorizes funding to establish cost-effective clean diesel projects.[3] This document will assist eligible entities with designing and implementing projects and will fulfill EPA's obligation under EPACT to provide information regarding the cost-effectiveness of eligible technologies for reducing emissions.[4]

EPA is issuing this document in fulfillment of these statutory requirements. States and local agencies involved with developing and implementing air pollution control programs should consult this information when making choices about investments to achieve air quality and public health goals. This document does not substitute for any applicable regulations, nor is it a regulation itself. It does not impose binding, enforceable requirements on any party and may not apply to a particular situation based upon the circumstances. EPA and State decision makers, as

[1] For a complete list of all EPA verified technologies, consult the list at the following web site: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Information on CARB's verification program can be accessed at: http://www.arb.ca.gov/diesel/verdev/verdev.htm."

[2] 23 U.S.C. Section 149(f)(2)

[3] The Diesel Emissions Reduction program can be found in Subtitle G of the Energy Policy Act of 2005. Section 792(c)(3) specifies cost effectiveness as a priority for evaluating projects.

[4] Section 793(b)(1)(C)

well as other interested parties are free to raise questions about the applicability of this information to a particular situation. The information in this document may be revised periodically without public notice as new data and research becomes available.

Background

In previous transportation legislation, Congress required the National Academy of Sciences (NAS) to evaluate the CMAQ Program. The results of the NAS CMAQ study demonstrate that certain CMAQ eligible activities can be far more cost-effective in generating emission reductions than others.[5] Furthermore, implementation of the 8-hour ozone and fine particulate matter ($PM_{2.5}$) National Ambient Air Quality Standards (NAAQS) underscores a need, in some areas, to identify additional local emission reduction activities that can help nonattainment areas meet the earliest of the NAAQS attainment dates (2010).

Retrofit projects can begin producing emission reductions immediately and can help State and local governments reduce emissions of $PM_{2.5}$, nitrogen oxides (NOx), and volatile organic compounds (VOC) in the near term. Retrofits include a wide range of emission reduction strategies available for diesel vehicles and equipment, including:

- Retrofitting engines with verified technologies
- Using cleaner fuels
- Replacing older equipment
- Repowering (replacing old engines with new, cleaner engines
- Reducing idling
- Properly maintaining equipment
- Gaining operational efficiencies

Retrofit technologies are advancing at a rapid pace. The use of established technologies, such as diesel oxidation catalysts (DOCs) and diesel particulate filters (DPFs), continues to grow exponentially, while new, emerging technologies such as Lean NOx (LNC) catalysts, are steadily improving. Retrofit technologies often vary in the type of pollutant reduced. DOCs and DPFs remove PM from the exhaust, but do not reduce NOx. However, DOCs or DPFs can be combined with a NOx reduction strategy – such as a cleaner fuel – to enhance the emission reduction benefits.

While retrofit technologies are one option for reducing diesel emissions, other options include cleaner fuels such as compressed natural gas (CNG) and the replacement of older engines and equipment. Cleaner fuels are becoming more prevalent throughout the country. The switch to ultra-low sulfur diesel (ULSD) fuel for highway engines enables advanced emissions reduction technologies to operate effectively (e.g. DPFs). Another option that can be applied to any vehicle or equipment is to reduce idling. Simply turning off the engine when the vehicle or

[5] Transportation Research Board. *The Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience.* Special Report 264. Washington, D.C.: 2002.

machine is not in use can reduce emissions as well as save fuel and minimize wear and tear on the engine.

As described below, diesel retrofits are especially important in areas facing immediate challenges to reduce $PM_{2.5}$ emissions and minimize the health impacts of diesel exhaust on its citizens. Some retrofits can provide benefits in the near-term by accelerating the use of new emission reduction technologies on existing older vehicles and engines. Otherwise, these vehicles and engines would continue emitting at higher rates throughout their useful lives. Given their immediate benefits, State and local agencies should work together to determine how retrofit projects could best be used, given local air quality characteristics. One option is to re-evaluate the programming of CMAQ funds with an emphasis on supporting $PM_{2.5}$ emission reduction strategies that can cost-effectively help areas attain the $PM_{2.5}$ NAAQS in 2010, reduce $PM_{2.5}$ health risks and meet their transportation conformity requirements.[6]

While SAFETEA-LU emphasizes eligibility and priority funding for retrofits, it is important to note that the CMAQ program is not the only funding resource available to support retrofit programs. Collaborations of federal, state, and local government agencies, nonprofit organizations, and industry, are working together to fund retrofit projects across the country. Information about these collaboratives and funding opportunities are available at: http://www.epa.gov/cleandiesel/grantfund.htm

Health Impacts

Reducing emissions from diesel engines is one of the most important public health challenges facing the country. EPA recently finalized two sets of clean fuel and vehicle emissions standards that will lead to dramatic emission reductions in new diesel-powered engines. Included within these rulemakings are cleaner fuel requirements, such as the use of ultra-low sulfur diesel, which will provide immediate emissions reductions in both new and older diesel engines.

Even with more stringent heavy-duty highway and nonroad engine standards set to take effect over the next decade, millions of diesel engines already in use will continue to emit large amounts of $PM_{2.5}$ emissions, which contribute to serious public health problems. These emissions cause thousands of premature deaths, hundreds of thousands of asthma attacks, millions of lost work days, and numerous other health impacts every year. There are almost 65 million people living in 120 counties with monitored $PM_{2.5}$ levels (2000–2002) exceeding the $PM_{2.5}$ NAAQS.

Diesel engines emit large amounts of nitrogen oxides and particulate matter. In 2004, diesel engines produced more than 6.2 million tons of NO_x and more than 300,000 tons of $PM_{2.5}$. Highway diesel engines accounted for approximately 50% of NO_x and 30% of $PM_{2.5}$ from the mobile source diesel sector. The freight sector's contribution to diesel emissions – which included rail movement for the first time in 2004 – was approximately 56% of NO_x and 32% of $PM_{2.5}$. Nonroad equipment accounted for 24% of NO_x and almost half of diesel $PM_{2.5}$ emissions

[6] On October 31, 2006, the U.S. Department of Transportation issued interim guidance for the CMAQ Program as reauthorized under SAFETEA-LU. This document is available electronically at http://www.fhwa.dot.gov/environment/cmaq06gm.htm

in 2004. While marine engines account for only 3% of diesel engines in 2004, port and non-port related marine emissions accounted for 16% of NO_x and 14% of PM of all mobile diesel sources.

EPA believes that diesel exhaust is likely to be carcinogenic to humans. The risk associated with exposure to diesel exhaust includes the particulate and gaseous components among which are benzene, formaldehyde, acetaldehyde, acrolein, and 1,3–butadiene, all of which are known or suspected human or animal carcinogens, or have noncancer health effects.[7] Specifically diesel exhaust has been judged to pose a lung cancer hazard for humans as well as a hazard from noncancer respiratory effects such as pulmonary inflammation. EPA assessed air toxic emissions and their associated risk (the National-Scale Air Toxics Assessment or NATA for 1999), and we concluded that diesel exhaust ranks with other substances that the national-scale assessment suggest pose the greatest relative risk.

Health effects associated with short-term variation in ambient PM have been indicated by epidemiologic studies showing associations between exposure and increased hospital admissions for ischemic heart disease, heart failure, respiratory disease, including chronic obstructive pulmonary disease (COPD) and pneumonia. Short-term elevations in ambient PM have also been associated with increased cough, lower respiratory symptoms, and decreases in lung function. Additional studies have associated changes in heart rate and/or heart rhythm in addition to changes in blood characteristics with exposure to ambient PM. Short-term variations in ambient PM have also been associated with increases in total and cardiorespiratory mortality.[8] Children are especially sensitive to diesel emissions compared to healthy adults because their respiratory systems are still developing and they have a faster breathing rate. Areas that are attaining the $PM_{2.5}$ standard may wish to consider these factors when planning on how to effectively remain in attainment and protect the public health.

Diesel exhaust also contributes to the formation of ground level ozone. While much has been accomplished in reducing ozone levels, ground-level ozone remains a pervasive pollution problem in many areas of the United States. Exposure to ozone has been linked to a number of health effects, including significant decreases in lung function, inflammation of the airways, and increased respiratory symptoms, such as cough and pain when taking a deep breath. Exposure can also aggravate lung diseases such as asthma, leading to increased medication use and increased hospital admissions and emergency room visits. Active children are the group at highest risk from ozone exposure because they often spend a large part of the summer playing outdoors. Children are also more likely to have asthma, which may be aggravated by ozone exposure. Other at-risk groups include adults who are active outdoors (e.g., some outdoor

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[7] U.S. EPA (2002) Health Assessment Document for Diesel Engine Exhaust. EPA/600/8-90/057F Office of Research and Development, Washington DC. This document is available electronically at http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29060

[8] U.S.EPA (1996) Air Quality Criteria for Particulate Matter, EPA 600-P-95-001aF, EPA 600-P-95-001bF. This document is available in Docket EPA-HQ-OAR-2005-0036. U.S. EPA (2004) Air Quality Criteria for Particulate Matter (Oct 2004), Volume I Document No. EPA600/P-99/002aF and Volume II Document No. EPA600/P-99/002bF. This document is available in Docket EPA-HQ-OAR-2005-0036. U.S. EPA (2005) Review of the National Ambient Air Quality Standard for Particulate Matter: Policy Assessment of Scientific and Technical Information, OAQPS Staff Paper. EPA-452/R-05-005. This document is available in Docket EPA-HQ-OAR-2005-0036.

workers) and individuals with lung diseases such as asthma and chronic obstructive pulmonary disease. In addition, long-term exposure to moderate levels of ozone may cause permanent changes in lung structure, leading to premature aging of the lungs and worsening of chronic lung disease.[9]

Ozone also affects vegetation and ecosystems, leading to reductions in agricultural crop and commercial forest yields, reduced growth and survivability of tree seedlings, and increased plant susceptibility to disease, pests, and other environmental stresses (e.g., harsh weather). In long-lived species, these effects may become evident only after several years or even decades and may result in long-term effects on forest ecosystems. Ground level ozone injury to trees and plants can lead to a decrease in the natural beauty of our national parks and recreation areas.

Cost-Effective Emission Reduction Activities

Cost-effectiveness, for the purpose of this document, is defined as the cost per ton of emissions reduced. Within this context, cost-effectiveness can vary depending on a number of factors. The pollutant(s) for which the area is in nonattainment, precursor pollutants of concern, relative size of pollutant inventories, and the existing sources and level of control measures in place can all influence cost-effectiveness. It is also important to note that cost-effectiveness does not necessarily correspond with overall effectiveness. For instance, a certain project or technology may be very cost-effective at reducing VOCs in an ozone nonattainment area, but if the project or technology only applies to very few emissions sources, or if the air quality chemistry in the ozone nonattainment area is NOx dependant, the overall effectiveness in reducing ozone may be quite limited.

Where essential emission reductions are more difficult to achieve, the acceptable cost of achieving those reductions could increase. Areas with more serious air quality problems typically will need to obtain greater levels of emissions reductions from local sources than areas with less serious problems, and it would be expected that their residents could realize greater health benefits from such reductions. It may be reasonable and appropriate for areas with more serious air quality problems to fund emission reduction requirements with generally higher costs per ton than the cost of emissions reductions in areas with less serious air quality problems. Given these considerations, EPA believes that it is not necessary to propose a fixed dollar per ton cost threshold for identification of cost-effective emission reduction activities.

Retrofitting diesel engines is, however, one of the most cost-effective ways to reduce diesel emissions. The term diesel retrofit includes any technology or system that achieves emission reductions beyond that required by the EPA regulations at the time of new engine certification. Diesel retrofit projects include the replacement of high-emitting vehicles/equipment with cleaner vehicles/equipment (including hybrid or alternative fuel models), repowering or engine replacement, rebuilding the engine to a cleaner standard, the purchase and installation of

[9] U.S. EPA. Air Quality Criteria for Ozone and Related Photochemical Oxidants (Final). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-05/004aF-cF, 2006. This document is available at: http://www.epa.gov/ttn/naaqs/standards/ozone/s_o3_cr_cd.html

advanced emissions control technologies (such as particulate matter traps or oxidation catalysts) or the use of a cleaner fuel. For example, diesel oxidation catalysts can result in a per vehicle particulate matter reductions of 20-40%. Diesel particulate filters reduce particulate matter up to 90% per vehicle.

To help stakeholders identify cost-effective technologies, EPA has developed a list of verified retrofit technologies that contains information on expected emission reduction benefits. This list provides information on numerous innovative emission control technologies that EPA has approved for receiving emission reduction credit. Each EPA verified technology has undergone extensive testing and analysis. The verification process includes evaluations of the emissions reduction performance of retrofit technologies- including the durability of the technologies- and identification of engine operating criteria and other conditions that must exist for these approved technologies to achieve the verified level of reductions. EPA evaluates each technology using a specific fuel, on a specific engine, and under specific loading cycles. The California Air Resources Board (CARB) has a verification process similar to EPA's verification process. EPA has signed a Memorandum of Agreement with CARB to recognize CARB's list of verified emission control options.[10] In addition, EPA has established a comprehensive list of idle-control technologies, which is available on the EPA website.[11]

To help stakeholders compare cost-effective strategies, EPA has included an appendix with 4 tables containing estimates of the cost per ton of pollutant reduced, for projects and programs that are potentially eligible for CMAQ funding. The estimates are derived from the best data available to EPA at the time this document was issued. The source of the information is identified for each project category.

The tables include cost-effectiveness estimates for reducing NOx and VOC precursor emissions for ozone and for PM emissions. As noted above, it is not always constructive to do a direct comparison between the cost-effectiveness of reducing different pollutants. For instance, PM and NOx cost-effectiveness are not comparable because the health effects, emissions inventories and control sources for the two pollutants are very different. Generally, emissions inventories show much greater amounts of NOx compared to PM. Correspondingly, greater reductions of NOx emissions are required to reduce ambient ozone levels than reductions of PM emissions required to reduce ambient PM levels. While reducing a ton of PM often costs more than to reduce a ton of NOx, the health effects of PM are greater per ton than for NOx. In addition to assessing the cost-effectiveness of reducing a pollutant, careful consideration should be given to the overall effectiveness of the reductions. Due to the greater health hazard posed by PM, a little PM reduction may be more effective than larger NOx reductions from a public health perspective.

Table 1 summarizes PM cost-effectiveness for typical diesel retrofit scenarios that utilize a diesel oxidation catalyst (DOC) or catalyzed diesel particulate filter (CDPF). These cost-effectiveness

[10] For a complete list of all EPA verified technologies, consult the list at the following web site: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm. The MOA can also be found at this web site.
[11] A list of idle-control technologies can be found at: http://www.epa.gov/otaq/smartway/idlingtechnologies.htm

estimates have not factored in the co-benefits from reducing other pollutants such as VOC. The cost-effectiveness of retrofitted programs can vary significantly depending on a number of factors, including actual annual average activity (i.e., annual vehicle miles traveled for highway or annual operating hours for nonroad). Table 2 is similar to Table 1 and contains PM cost-effectiveness for typical nonroad retrofit projects utilizing a diesel oxidation catalyst (DOC) or catalyzed diesel particulate filter (CDPF). More information about the data and the methodology used to develop these tables is in EPA's technical report entitled "Diesel Retrofit Technology: An Analysis of the Cost Effectiveness of Reducing Particulate Matter Emissions from Heavy-Duty Diesel Engines Through Retrofits." This report can be found at: http://www.epa.gov/cleandiesel/publications.htm

Table 3 summarizes the cost-effectiveness of some specific voluntary mobile source emission reduction programs supported by EPA's Office of Transportation and Air Quality. These voluntary programs aim to achieve cost-effective emission reductions without the need for regulation. These programs are implemented through partnerships with small and large businesses, citizen groups, industry, manufacturers, trade associations, and state and local governments. More information about these programs can be found at: http://epa.gov/otaq/voluntary.htm

Table 4 contains project and program categories taken from the study by the NAS in 2002. The NAS CMAQ study assessed the cost-effectiveness of various CMAQ-eligible strategies to reduce emissions. The study estimated the cost-effectiveness of projects based on cost (in calendar year 2000 dollars) per ton of emissions (VOC and NOx) reduced. To bring the cost estimates current, EPA adjusted the NAS's estimates to 2006 dollars according to the consumer price index established by the Bureau of Labor Statistics, U.S. Department of Labor. Recognizing that ozone levels in many nonattainment areas are more dependant on NOx than on VOCs, and consistent with the NAS methodology, the Table 4 estimates assume a benefit weighting ratio of 4:1 for NOx:VOC. This approach to weighting is commonly used to calculate one cost-effectiveness value for multiple pollutant reductions. The weighting factors are determined on the basis of relative damage values of the individual pollutants. The damage value of a given pollutant is estimated through modeling of air quality, assessing human and environmental exposure, and then applying a valuation to the health and environmental effects of the exposure.

It is important to note that while the estimates reflect the best available data at the time, there are limitations inherent in such an assessment. The data presented are based on a select sampling of projects that may not completely capture the potential cost-effectiveness of other techniques of implementing particular strategies. Therefore, the median cost should be considered along with the cost range to better portray a project's potential cost-effectiveness. Further analysis is recommended in order to assess the cost-effectiveness and emission reduction potential of specific projects or programs. EPA provides models for estimating the transportation sector's impacts on emissions. Emissions estimates from these models can be used for evaluating the impact and cost-effectiveness of various emissions control strategies.[12]

National Ambient Air Quality Standards

Consistent with the statutory provisions of SAFETEA-LU regarding CMAQ funding priority for diesel retrofits, implementation of the NAAQS for $PM_{2.5}$ and 8-hour ozone also highlights the critical need to target CMAQ funds to diesel engine retrofits and the most cost-effective emission reduction activities. While substantial emission reductions have been achieved in the mobile source sector, recent data show that mobile sources remain a major source of air pollution in most nonattainment areas.[13]

Many States and MPOs with $PM_{2.5}$ nonattainment areas face a unique challenge in that their CMAQ funds have been previously allocated to support attainment of the ozone NAAQS. The initial statutory attainment date for the current $PM_{2.5}$ NAAQS is as expeditiously as practical but no later than 2010 and emission reductions needed to attain the standard must be in place at the beginning of 2009.[14] States are required to submit $PM_{2.5}$ state implementation plans (SIPs) in 2008 to demonstrate how the nonattainment areas will attain the $PM_{2.5}$ NAAQS. Therefore, it is particularly urgent that States and MPOs in $PM_{2.5}$ areas begin now to direct CMAQ resources to the control of diesel emissions.

States and MPOs in 8-hour ozone nonattainment areas should also consider how CMAQ resources can be used to fund retrofit projects and other cost-effective measures to help attain the 8-hour ozone NAAQS. Eight-hour ozone nonattainment areas have varying attainment dates depending on the level of their ozone concentrations. Some areas may need to implement local control measures to achieve emission reduction in advance of the timeframe for emission reductions projected to be achieved by national control measures. States and MPOs are also required to meet the transportation conformity requirements of section 176(c) of the CAA. Transportation conformity ensures that emissions that result from an area's transportation system stay within the limits established in the SIP. In some $PM_{2.5}$ and 8-hour ozone areas, staying within these emissions limits may necessitate additional controls, potentially including diesel emission reduction strategies.

On September 21, 2006, EPA issued new standards which strengthen the 24-hour $PM_{2.5}$ standard. EPA anticipates that attainment (meeting the standards) and nonattainment (violating the standards) designations for areas with respect to the new standard will become effective in

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[12] For more information, see: http://www.epa.gov/otaq/models.htm and http://www.epa.gov/omswww/stateresources/tools.htm EPA has also recently released a quantification tool for estimating environmental impacts and cost effectiveness of emissions reduction technologies added to vehicles and equipment. The Diesel Emissions Quantifier can be accessed at: http://cfpub.epa.gov/quantifier/

[13] See the EPA Clearinghouse for Inventories and Emissions Factors - 2002 National Emissions Inventory Data and Documentation. http://www.epa.gov/ttn/chief/net/2002inventory.html

[14]Because the current $PM_{2.5}$ designations were effective in 2005, areas must demonstrate attainment as expeditiously as practical but no later than 2010. However, Clean Air Act section 172 (a)(2)(A) allows areas to request that the attainment date be extended by up to five additional years if they can justify the need for such an extension based on the severity of the nonattainment problem and the availability and feasibility of control measures.

April 2010.[15] States with nonattainment areas must submit plans by April 2013 to demonstrate how they will attain the standards by 2015. While the most pressing need for the states is to develop local measures to meet the current $PM_{2.5}$ standard, the further tightening of the $PM_{2.5}$ standard and the retention of the 24-hour coarse PM standard may create an additional need for reductions in the period from 2010 to 2015.

For these reasons, EPA strongly recommends that States and MPOs re-evaluate their current and proposed transportation plans and CMAQ activities to ensure an appropriate balance in projects to support attainment of the $PM_{2.5}$ and 8-hour ozone NAAQS.

EPA Emission Reduction Guidance and Cost Effectiveness Resources

EPA, in consultation with DOT and stakeholders, has developed several guidance documents to help MPOs and others take emission reduction credit for CMAQ (or other) funded activities that retrofit diesel engine trucks, nonroad equipment (such as construction and locomotives), school buses, reduce idling from diesel trucks, and support strategies to reduce drive-alone commutes. In addition, EPA has released quantification tools for estimating the environmental impacts and cost effectiveness of emission reduction technologies to vehicles and equipment. These documents and resources are:

- U.S. EPA. Diesel Retrofits: *Quantifying and Using Their Benefits in SIPs and Conformity. Guidance for State and Local Air and Transportation Agencies*. EPA420-B-06-005. http://www.epa.gov/otaq/stateresources/transconf/policy/420b06005.pdf

- U.S. EPA. *Guidance for Quantifying and Using Long-Duration Truck Idling Emission Reductions in State Implementation Plans and Transportation Conformity*. EPA420-B-04-001. January 2004. http://www.epa.gov/smartway/idle-guid.htm

- U.S. EPA. *The Diesel Emissions Quantifier (DEQ).* This on-line interactive tool estimates the emissions reductions of clean diesel projects and their cost effectiveness. Accessible at: http://www.epa.gov/cleandiesel/

- U.S. EPA. *National Mobile Inventory Model.* This model estimates emissions from highway vehicles and nonroad equipment. Accessible at: http://www.epa.gov/otaq/nmim.htm

- U.S. EPA. *Smartway Technology Package Savings Calculator.* This calculator is designed to help truck owners compare the costs and estimate the fuel savings associated with various efficiency technologies. Accessible at: http://www.epa.gov/smartway/calculator/loancalc.htm

[15] Clean Air Act section 107(d)(1)(B) requires EPA to promulgate designations within two years of the promulgation or revision of a NAAQS. However, this time period may be extended for up to one year if there is insufficient information to promulgate the designations.

- U.S. EPA. *Guidance for Quantifying and Using Emission Reductions from Best Workplaces for Commuter Programs in State Implementation Plans and Transportation Conformity*. EPA420-B-05-016. October 2005. http://www.epa.gov/otaq/stateresources/policy/transp/commuter/420b07015.pdf

- U.S. EPA. *Diesel Retrofit Technology: An Analysis of the Cost Effectiveness of Reducing Particulate Matter Emissions from Heavy-Duty Diesel Engines Through Retrofits.* EPA420-S-06-002. March 2006. http://www.epa.gov/cleandiesel/publications.htm

- U.S. EPA. *Diesel Retrofit Technology: An Analysis of the Cost Effectiveness of Reducing Particulate Matter and Nitrogen Oxides Emissions from Heavy-Duty Nonroad Diesel Engines Through Retrofits.* EPA420-R-07-005. May 2007. http://www.epa.gov/cleandiesel/publications.htm

- U.S. EPA. *Guidance for Quantifying and Using Long-Duration Switch Yard Locomotive Idling Emission Reductions in State Implementation Plans.* EPA420-B-04-002. January 2004. http://www.epa.gov/smartway/idle-guid.htm

EPA has prepared these documents and resources to help States and MPOs estimate emission benefits. The guidance documents address how to take credit for them in SIPs and conformity determinations. These activities can be incorporated into the SIP as mandatory measures or as a voluntary mobile source measure as appropriate. Additional guidance documents and other information resources from EPA's Office of Transportation and Air Quality are available at: www.epa.gov/otaq

APPENDIX

Table 1. Summary of Cost-Effectiveness for Various Diesel PM Retrofit Scenarios

Vehicle	Retrofit Technology*	Range of $/ton PM Emission Reduced**	
School Bus	DOC	$12,000	$49,100
	CDPF	$12,400	$50,500
Class 6&7 Truck	DOC	$27,600	$67,900
	CDPF	$28,400	$69,900
Class 8b Truck	DOC	$11,100	$40,600
	CDPF	$12,100	$44,100
250 hp Bulldozer	DOC	$18,100	$49,700
	CDPF	n/a	n/a

* Retrofit technologies include diesel oxidation catalyst (DOC) and catalyzed diesel particulate filter (CDPF)
** The cost per ton of PM reduced will depend on a variety of factors including the age and activity levels of the vehicles or equipment. Source: U.S. EPA. *Diesel Retrofit Technology: An Analysis of the Cost Effectiveness of Reducing Particulate Matter Emissions from Heavy-Duty Diesel Engines Through Retrofits*. EPA420-S-06-002. March 2006. http://www.epa.gov/cleandiesel/publications.htm

APPENDIX

Table 2. Summary of Cost-Effectiveness for Various Nonroad Diesel PM Retrofit Scenarios

Equipment	**Retrofit Technology***	**Range of $/ton of PM Reduced****	
Off-highway trucks	DOC	$21,700	$78,800
	CDPF	$24,200	$87,600
Loaders/Backhoes/Tractors	DOC	$25,900	$49,900
	CDPF	$28,800	$55,400
Excavators	DOC	$22,300	$61,900
	CDPF	$24,800	$68,800
Cranes	DOC	$20,900	$60,000
	CDPF	$23,300	$66,700
Generator Sets	DOC	$18,700	$46,100
	CDPF	$20,800	$51,300

* Retrofit technologies include diesel oxidation catalyst (DOC) and catalyzed diesel particulate filter (CDPF)
** The cost per ton of PM reduced will depend on a variety of factors including the age and activity levels of the vehicles or equipment. Source: U.S. EPA. *Diesel Retrofit Technology: An Analysis of the Cost Effectiveness of Reducing Particulate Matter and Nitrogen Oxides Emissions from Heavy-Duty Nonroad Diesel Engines Through Retrofits.* EPA420-R-07-005. May 2007. http://www.epa.gov/cleandiesel/publications.htm

APPENDIX

Table 3. Summary Cost-Effectiveness of EPA Voluntary Mobile Source Programs (4:1 weighting of NOx;VOC)

Activity	Description	Median Cost	Cost Range		Sources
Advanced Truck Stop Electrification	Advanced truck stop electrification provides a parked truck with electrical power, and heating, cooling, and other amenities like telecommunication hook ups, through an external console that fits into the truck's window frame.	$1,700	$1,400	$2,000	1
Truck Auxiliary Power Units	An APU consists of a small engine and generator that provides power to the truck when the main engine is shut off. It power s heating, air conditioning, and electrical accessories for the cab and sleeper.	$3,100	$2,700	$3,500	2
Diesel Retrofits	Examples of diesel retrofits include engine upgrades, engine repowers or replacements, cleaner fuels, emissions control technologies, or idle controls.	$5,950*	$1,900*	$19,000*	3
Best WorkPlaces for Commuters	Best Workplaces for Commuters^{SM} is a voluntary business-government program that distinguishes and provides national recognition to employers offering outstanding commuter benefits such as free or low cost bus passes, strong telework programs, carpooling matching and vanpool subsidies. www.bwc.gov	$19,200	$19,200	$19,200	4

Sources: (1)NOx emission factor based on EPA engine idling testing (see http://www.epa.gov/smartway/idle-guid.htm); assumes activity level of 40%-50% (or 9.6 -12 hours/day) utilization of one electrified parking space over 365 days/year (06/28/06 interview, Tom Badgett, Chief Information Officer, IdleAire Technologies, Inc.; assumes 20 year service life (06/26/06 interview, Tom Badgett); assumes $17K per space (see Texas A&M Research Foundation, Request for Proposals #B001498, http://rf-web.tamu.edu/); (2)Assumes 2,000 hour/year usage (interview with 3 leading APU manufacturers – Teleflex/Carrier, Rig Master, Thermo King; assumes NOx offset from APU at 23 g/hr (see http://www.epa.gov/smartway/idle-guid.htm; assumes10 year service life (interview with APU manufacturers); assumes $7K per unit (see American Transportation Research Inst. RFP #3-14-1104). (3) NOx reduction based on applying the methodology outlined in the technical paper "*Diesel Retrofit Technology: An Analysis of the Cost-Effectiveness of Reducing Particulate Matter Emissions from Heavy-Duty Diesel Engines Through Retrofits***"** to a select group of NOx reducing retrofit technologies. The cost per ton of NOx reduced will depend on a variety of factors including the age and activity levels of the vehicles or equipment and the technology utilized. These cost figures only account for NOx reductions and do not factor in VOC reductions. Consequently, the 4:1 NOx:VOC weighting does not apply. (4) Best Workplaces for Commuters: E.H. Pechan and Associates, Inc., *PM NAAQS Mobile Modeling Technical Memorandum*. Prepared for U.S.EPA. July 2006.

APPENDIX

Table 4. Cost-Effectiveness of Various Mobile Source Projects (4:1 weighting of NOx:VOC)

Activity	**Description**	**Median Cost (2006 dollars per ton)**	**Cost Range (2006 dollars per ton)**	
Inspection and Maintenance	Typically pays for the operating expenses of I&M programs	$2,200	$2,100	$6,800
Regional Rideshare	Regional rideshare programs provide marketing, administrative and limited operating costs for area-wide carpool and ridesharing programs.	$8,700	$1,400	$18,700
Vanpool Programs	Similar to regional rideshare but focused on support and promotion of vanpools.	$12,300	$6,100	$104,200
Travel Demand Management	Usually informational and promotional programs administered by governments, public agencies and public-private partnerships. Often implemented at the employer level, utilizing ridesharing, transit and parking strategies	$14,600	$2,700	$38,900
Conventional Fuel Bus Replacement	Replace pre-1991 model year diesel buses with post-1996 diesel buses. Emission reductions and cost-effectiveness decrease rapidly if replacing newer buses	$18,800	$12,900	$46,700
Alternative Fuel Non-Transit Vehicles	Electric, CNG, LPG Vehicles and fueling facilities	$20,800	$4,700	$37,000
Traffic Signalization	Traffic signal inter-connection and timing optimization to reduce stop-and-go traffic.	$23,500	$7,000	$149,900

APPENDIX

Table 4. Continued

Employer Trip Reduction	Individual programs can vary widely. Can be voluntary or mandatory for employers but usually voluntary for employees. Employers offer workplace, work schedule, transportation and parking options along with incentives and disincentives for employee participation	$26,600	$6,800	$205,500
Transit - Conventional Service Upgrades	Consists largely of improved frequency of fixed-route bus service.	$28,800	$4,400	$140,600
Park & Ride Lots	Capital costs for construction of parking lots to support rideshare, express bus, HOV lanes	$50,300	$10,100	$82,800
Modal Subsidies & Vouchers	Temporary subsidies to support new transit, carpool, or vanpool programs	$54,600	$900	$551,400
Transit - New Fixed Guideway and Equipment	Mostly fixed transit-ways and commuter rail capital investments. High initial capital costs, mediated by long service lives and projected long-term increases in ridership can produce favorable cost-effectiveness.	$77,700	$10,000	$551,200
Bicycle and Pedestrian Programs	Construction of new bicycle or pedestrian facilities, improved access to transit and activity centers, and education and safety program.	$98,500	$4,900	$403,600
Transit - Shuttles, Feeders, and Paratransit	Usually this is service and/or facilities to supplement regular public transportation routes. Shuttles and feeders are generally focused on specific corridors with identified demand for transit access. Paratransit serves wider areas with less demand - usually reflected in higher costs and lower impacts	$102,400	$14,400	$2,311,000
Alternative Fuel Transit Vehicles and Facilities	Predominately CNG replacement buses and shuttles	$148,000	$7,800	$665,800

Source: (1) Transportation Research Board. The Congestion Mitigation and Air Quality Improvement Program: Assessing Ten Years of Experience. Special Report 264. Washington, D.C.: 2002. In calculating cost-effectiveness, TRB assumed a weighting scheme of 1:4 for VOC:NOx. EPA has adjusted the TRB's calculations for inflation according to the consumer price index established by the Bureau of Labor Statistics, U.S. Department of Labor.