Cleaner Diesel Handbook

BRING CLEANER FUEL AND DIESEL RETROFITS INTO YOUR NEIGHBORHOOD

APRIL 2005

ENVIRONMENTAL DEFENSE
finding the ways that work

Cleaner Diesel Handbook

BRING CLEANER FUEL AND DIESEL RETROFITS INTO YOUR NEIGHBORHOOD

APRIL 2005

AUTHORS

Janea Scott

Isabelle Silverman

Stephanie Tatham

environmental defense

finding the ways that work

Cover images: Courtesy of Johnson Matthey (left), Environmental Defense (right).

Our mission
Environmental Defense is dedicated to protecting the environmental rights of all people, including the right to clean air, clean water, healthy food and flourishing ecosystems. Guided by science, we work to create practical solutions that win lasting political, economic and social support because they are nonpartisan, cost-effective and fair.

The complete report is available online at www.environmentaldefense.org.

Contents

Executive summary

Cost-effective steps to reducing diesel pollution

Environmental Defense's *Cleaner Diesel Handbook* is designed to empower the private sector, public officials and ordinary citizens with the means to reduce harmful pollution from diesel engines. This handbook focuses on methods of reducing pollution created by diesel engines, especially those used in construction and other nonroad sectors. The nonroad sector includes vehicles not typically found on roads, such as agricultural equipment, locomotives, ferries, snowmobiles and airplanes. Construction equipment is part of the nonroad sector. Collectively, nonroad engines discharge more dangerous fine sooty particles than any other source in the transportation sector. The solutions described here can reduce these harmful emissions by up to 90% and are a cost-effective response to the challenge of improving local air quality.

The health imperative: half of Americans live with unhealthy air

Diesel engines emit nearly 40 toxic substances, smog-forming oxides of nitrogen and fine particulate matter, and they contribute to a laundry list of adverse health effects including: asthma, cardiovascular and respiratory problems, strokes, heart attacks, lung cancer and premature death. Diesel exhaust is estimated to contribute to more than 75% of the added cancer risk from air toxics in the United States. Of special concern are two main pollutants: fine particulate matter, which lodges deep in the lungs, and oxides of nitrogen (NO_x), which are precursors to smog. Both can be reduced substantially with the tools described in this handbook.

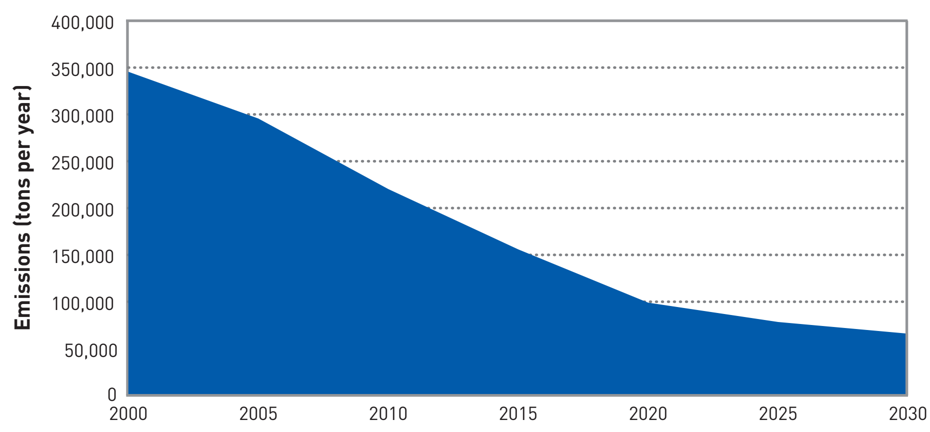
Recent data from the U.S. Environmental Protection Agency (EPA) shows that about half of all Americans live in places that fail to meet basic health standards for ozone (smog), fine particulates (soot) or both. On April 15, 2004, EPA found 474 counties—home to 159 million Americans—out of full compliance with the health-based eight-hour ozone standard. NO_x is a significant precursor in the formation of ground-level ozone and nonroad engines, as a vehicle class, emit almost one-fifth (more than 4 million tons) of the total national NO_x emissions from all sources.

As of April 2005, EPA classified 208 counties spanning 20 states as being out of full compliance with the health-based fine particulate ($PM_{2.5}$) standard. More than 57 million Americans live in counties that are not meeting the health-based particulate pollution standard. For the states and local communities that are struggling to trim every possible ton of pollution to meet federal health-based air quality standards and protect the health of their community, reducing pollution from existing diesel vehicles and equipment now is vitally important.

Cleaner air: bridging the 25-year gap

On May 10, 2004, EPA announced new air pollution regulations that will significantly lower pollution from new nonroad diesel engines used in construction, agriculture, manufacturing and services. As old diesel equipment is replaced over the coming years, this rule will deliver important public health benefits to communities across America. But the full pollution reductions and

FIGURE 1
Particulate pollution under phase-in of federal standards for diesel trucks, buses, and machinery



National $PM_{2.5}$ emissions under phase-in of federal standards for onroad diesel trucks and buses, and nonroad diesel equipment. (Estimated from EPA, 2000 and EPA, 2004a)

public health benefits of this rule will not be realized for more than 20 years due to the lag in time before the emissions standards come into effect and because of the long life spans of heavy-duty diesel engines. Many nonroad engines, like those used on construction or marine vehicles, may have life spans of several decades. A child born today may still be breathing soot from a backhoe in her neighborhood when she graduates from college—unless that backhoe is replaced with a clean one or retrofit with emissions controls.

Figure 1 shows national particulate pollution under the phase-in of the federal emissions standards for diesel trucks, buses and nonroad machinery.

While the health benefits from full implementation of EPA national diesel emissions standards are extremely important, the incremental phase-in of these benefits indicates that thousands of premature deaths each year could be prevented by speeding the cleanup of diesel engines. The shaded area under the curve represents the pollution a retrofit program could prevent.

Cost-effective diesel pollution reduction

This handbook demonstrates that cleaning up diesel engines is a cost-effective way to reduce the adverse health effects of diesel pollution and outlines some simple steps, like enforcing idling laws and using clean fuels—like ultra-low sulfur diesel (ULSD)—with best available retrofit technologies that can cut diesel emissions by up to 90%.

The three "Rs" of emissions reduction

Repower. Replace the engine, or entire vehicle, with newer, cleaner technologies that meet or exceed EPA's newest standards and/or uses alternative fuels.
Refuel. Alternative fuels, ultra-low sulfur diesel fuel and other clean fuels or additives are important first steps.
Retrofit. Reduce diesel exhaust with best available pollution control technology.

The handbook describes the "3Rs" of engine operations, as well as the use of best practices in equipment management. It gives particular attention to the subjects of cleaner fuels and retrofit technologies. The main goal is to reduce emissions of both fine particulate matter and NO_x. Appendices to the handbook will include some information on the manufacturers of retrofit technology and distributors of cleaner fuels. Together, this information is meant to serve as a starting point for anyone seeking to cut harmful diesel pollution.

Right now, there are a variety of cleaner fuels and demonstrated retrofit technologies available to reduce emissions of particulate matter (PM), oxides of nitrogen (NO_x), hydrocarbons (HC), carbon monoxide (CO), smoke and odor from existing diesel engines. It is important to remember that not all technologies and fuels target the same pollutants, and that appropriate technologies or fuels may vary in different contexts. Generally, a combination of multiple technologies and emissions control strategies is necessary for maximum emissions reduction.

In addition to describing the tools available for diesel pollution reduction, this handbook examines a variety of methods for implementing successful retrofit programs. The handbook provides examples of successful programs such as government and private sector efforts, contract specifications, voluntary retrofit programs, and economic or market incentive programs that provide financial support for cleaner technology or fuels.

Ultimately, the handbook demonstrates the need to reduce diesel engine emissions and presents the means to design and implement measures to clean up diesel technology. Together, these tools can be used to build a successful retrofit program in any community.

CHAPTER 1

Introduction: achieving cleaner, healthier air today

Science is very clear that air pollution from diesel engines endangers human health. Fortunately, cost-effective and practical technologies exist to substantially reduce diesel pollution. Across the country, we find successful diesel emissions-reduction programs, from school buses and trucks to construction equipment and ferries. Such programs can cut diesel pollution from targeted fleets by up to 90%. Yet far too many communities still have not taken advantage of these opportunities to win healthier air. This handbook is a guide to how to bring that success to your community, your company and your local government.

The purpose of this handbook is to provide practical information for decision-makers in the public and private sectors to use in creating and implementing effective emissions-reduction projects for construction and other nonroad diesel fleets.[1] Because the nonroad sector is so dirty, and because the emissions-reduction solutions are not yet widely disseminated for this sector, this handbook focuses attention on construction fleets and other nonroad applications. The handbook's basic concepts, however, are applicable across the diesel sector.

This handbook sets forth:

- the health imperative for reducing diesel pollution today;
- an overview of technologies and fuels that can reduce diesel pollution, with detailed follow-up information;
- information about successful retrofit programs;
- examples of contract specifications and other incentives for cleaning diesel engines.

Together, these tools can be used by any citizen concerned about diesel pollution to inform local policymakers and contractors about the benefits of, and the steps involved in, implementing a successful retrofit program.

This handbook focuses on how to reduce pollution from vehicles, engines and equipment used for construction. Construction vehicles are classified as "mobile sources" because they move. Mobile sources are divided into the "onroad" and "nonroad" sectors. The onroad sector includes vehicles used on roads for transportation of passengers or freight.

The nonroad sector includes vehicles that are not typically found on roads, such as agricultural equipment, locomotives, ferries, snowmobiles and airplanes. Construction equipment is part of the nonroad sector. However, the technologies, fuels, and techniques found herein are frequently applicable across the diesel sector (onroad engines and other nonroad engines) as well. For more information, visit the EPA Mobile Source web site at: http://www.epa.gov/otaq/invntory/overview/examples.htm.

Since 1996, EPA has required new nonroad diesel engines to meet specific emissions levels. Until 1996, those standards were not very strong, and as a result they allowed for high levels of pollution. On May 10, 2004, EPA announced air pollution regulations that will lower pollution from *new* nonroad diesel engines used in construction, agriculture, manufacturing and services by more than 90%.

To meet this rigorous emissions standard, EPA requires a combination of cleaner engines, pollution control technology and cleaner fuel. Based on

EPA estimates, when the full inventory of older nonroad engines has been replaced, the nonroad diesel program will annually prevent up to 12,000 premature deaths, one million lost work days, 15,000 heart attacks and 6,000 children's asthma-related emergency room visits.[2] According to EPA, the overall benefits of the nonroad diesel program outweigh the costs by a ratio of 40 to 1.[3]

But the full pollution reduction and public health benefits of the nonroad rule will not be realized for more than 20 years due to the lag in time before the emissions standards come into effect and because of the long life spans of heavy-duty diesel engines. EPA estimates that by 2030 the entire inventory of nonroad vehicles covered by this new rule should be upgraded.[4]

Given that nonroad engines remain in use for a very long time, even decades, strategies to retrofit existing machinery and the use of ultra-low sulfur diesel (ULSD) fuel are extremely important to win public health gains now. Figure 1 (page v) shows the national particulate pollution under the phase-in of the federal emissions standards for diesel trucks and buses, and nonroad machinery.

The public health benefits will likewise be phased in over time. EPA estimates, for example, that only about 30% of the ultimate level of annual benefits under its recently announced standards for nonroad diesel engines will be realized by 2015; just over 50% will be realized by 2020. While the health benefits from full implementation of EPA national diesel emissions standards are extremely important, the incremental phase-in of these benefits indicates that thousands of premature deaths each year, occurring now, could be prevented by accelerating the cleanup of diesel engines.

Right now, there are a variety of demonstrated retrofit technologies available to reduce particulate matter (PM), oxides of nitrogen (NO_x), hydrocarbon (HC), carbon monoxide (CO), smoke and odor created by existing diesel engines. Therefore, programs to reduce pollution from existing diesel engines are critical. This handbook explores a variety of methods for implementing successful retrofit programs.

Children are particularly vulnerable to the harmful health effects of diesel exhaust.

ENVIRONMENTAL DEFENSE

CHAPTER 2

The dangers of diesel emissions

According to recent EPA data, about half of all Americans now live in counties that fail to meet basic healthy air standards. On April 15, 2004, EPA found 474 counties, home to 159 million Americans, out of full compliance with the health-based eight-hour ozone standard.[5] In April 2005, EPA also found 208 counties representing more than 57 million Americans out of full compliance with the health-based particulate pollution standard.[6]

For the states and local communities that are struggling to trim every possible ton of pollution to meet federal health-based air quality standards, reducing pollution from existing diesel vehicles and equipment now is vitally important. Retrofits and the use of clean fuels are one of the most cost-effective ways to reduce diesel emissions and restore healthy air.

Diesel engines, including the construction engines that are the focus of this handbook, emit nearly 40 toxic substances (Table 1), smog-forming oxides of nitrogen and fine particulate matter ($PM_{2.5}$), which can penetrate the lungs and enter the bloodstream. Due to their small size, particulates are easily inhaled and reach deep into the lungs where they can trigger an inflammatory response. Exposure to particulate matter is associated with heart attacks, irregular heartbeat, asthma attacks, reduced lung function and bronchitis.

Several organizations, including EPA, have designated diesel exhaust as a probable or potential human carcinogen (Table 2). It is estimated that diesel exhaust contributes more than 70% of the cancer risk from air toxics in the United States.[7] Diesel emissions are also estimated to be the hazardous air pollutant with the highest contribution to cancer risk in many areas across the country;[8] according to Environmental Defense's Scorecard, this is true in New York, Los Angeles, Houston, Denver, Chicago and Atlanta.[9]

Smog-forming nitrogen oxides

Nitrogen oxides (NO_x) and volatile organic compounds (VOCs) that are created by diesel exhaust are precursors to ground-level ozone, or smog. Nonroad engines, as a vehicle class, also emit more than 4 million tons of NO_x each year—this is approximately 19% of the total national NO_x emissions from all sources (22,349,000 tons).[10] As well as being significant contributors to ground-level ozone or smog, nitrogen oxides are also significant contributors to acid deposition, eutrophication of coastal bodies of water, fine particulate emissions and haze.

Fine particulate matter

There is a well-researched body of epidemiological studies from around the world that documents the serious threats associated with exposure to $PM_{2.5}$. These studies have linked $PM_{2.5}$ to adverse health effects, such as asthma, cardiovascular and respiratory problems, strokes, heart attacks[11] and lower birth weight[12] leading to increased use of asthma medications, doctor visits, emergency room visits, hospital admissions, school absenteeism and premature death.[13] Researchers estimate that as many as 60,000 Americans die prematurely each year because of exposure to fine particles.[14] Children, the elderly and the ill are particularly vulnerable. National $PM_{2.5}$ emissions from mobile sources totaled approximately 452,000 short tons in 2001. Nonroad vehicles created the majority of those emissions, 64%, and almost 50% of total $PM_{2.5}$ emissions originated from nonroad diesel sources (221,000 short tons). Construction and surface mining equipment was the largest contributor (30%) to nonroad diesel source $PM_{2.5}$ emissions.

Asthma

People working at and living near construction sites are especially affected by nonroad vehicles' emissions. In urban areas, overall asthma prevalence has increased dramatically over the past two decades, rising 75% between 1980 and the average in 1993–4. While the highest prevalence of asthma is in children ages 5 to 14, the greatest increase in asthma prevalence has occurred in children ages 0 to 4 which increased 160% over the 15-year period.[15] For example, New York City residents suffer from alarmingly high asthma rates (1 out of every 8 adults has been diagnosed with asthma at some point in their lives[16]) and New York City air fails to meet many basic health standards. To learn about air quality conditions in your area, visit Environmental Defense's Scorecard web site at: http://www.scorecard.org/.

TABLE 1
Toxic air contaminants and hazardous air pollutants found in diesel exhaust

Acetaldehyde*	Chlorine	Methyl ethyl ketone
Acrolein	Chlorobenzene	Naphthalene*
Aluminum	Chromium compounds*	Nickel*
Ammonia	Cobalt compounds*	4-nitrobiphenyl*
Aniline*	Copper	Phenol
Antimony compounds*	Cresol	Phosphorus
Arsenic*	Cyanide compounds	POM (including PAHs)
Barium	Dibenzofuran	Propionaldehyde
Benzene*	Dibutylphthalate compounds*	Selenium
Beryllium compounds*	Ethyl benzene	Silver
Biphenyl	Formaldehyde*	Styrene*
Bis [2-ethylhexyl} phthalate*	Hexane	Sulfuric acid
Bromine	Lead compounds*	Toluene*
1,3-butadiene*	Manganese compounds	Xylene isomers and mixtures
Cadmium*	Mercury compounds*	Zinc
Chlorinated dioxins*	Methanol	

*This compound or class of compounds is known by the state of California to cause cancer or reproductive toxicity. See California EPA, Office of Environmental Health Hazard Assessment, "Chemicals Known to the State to Cause Cancer or Reproductive Toxicity," May 31, 2002.

Note: Toxic air contaminants on this list either have been identified in diesel exhaust or are presumed to be in the exhaust, based on observed chemical reactions or presence in the fuel or oil. See California Air Resources Board, "Toxic Air Contaminant Identification List Summaries, Diesel Exhaust," September 1997, available online at http://www.arb.ca.gov/toxics/tac/factshts/diesex.pdf.

TABLE 2
History of determinations of the carcinogenicity of diesel exhaust

Year	Agency	Determination
1988	National Institute for Occupational Safety and Health (NIOSH)	Potential occupational carcinogen
1989	International Agency for Research on Cancer (IARC)	Probable human carcinogen
1990	State of California (under provisions of Proposition 65)	Known by the state to cause cancer
1995	Health Effects Institute (HEI)	Potential to cause cancer
1996	World Health Organization International Programme on Chemical Safety (WHO-IPCS)	Probable human carcinogen
1998	California Air Resources Board (CARB)	Toxic air contaminant (determination based substantially on the cancer risk to humans)
2000	U.S. Department of Health and Human Services National Toxicology Program (U.S. DHHS/NTP)	Reasonably anticipated to be human carcinogen
2001	American Council of Government Industrial Hygienists (ACGIH) (proposed)	Suspected human carcinogen
2002	U.S. Environmental Protection Agency (EPA)	Probable human carcinogen

Sources:

National Institute for Occupational Safety and Health, "Carcinogenic Effects of Exposure to Diesel Exhaust," Current Intelligence Bulletin 50. August 1988. Available online at http://www.cdc.gov/niosh/88116_50.html . Last accessed August 13, 2004.

International Agency for Research on Cancer (IARC), Diesel and Gasoline Engine Exhausts and Some Nitroarenes. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans, no. 46 (Lyons: World Health Organization, 1989), pp. 41-185.

California Environmental Protection Agency, Chemicals Known to the State to Cause Cancer or Reproductive Toxicity (Proposition 65, 1997), revised May 31, 2002.

Health Effects Institute, Diesel Exhaust: A Critical Analysis of Emissions, Exposure and Health Effects. Cambridge, MA: Health Effects Institute, 1995. Online resource, available at: http://www.healtheffects.org/Pubs/diesum.htm Last accessed on August 13, 2004.

American Conference of Governmental Industrial Hygienists, "Documentation of the Threshold Limit Values and Biological Exposure Limits, Notice of Intended Changes," 2001.

International Programme on Chemical Safety, World Health Organization, "Diesel Fuel and Exhaust Emissions," Environmental Health Criteria 171 (1996).

"The Toxic Air Contaminant Identification Process: Toxic Air Contaminant Emissions from Diesel-fueled Engines," fact sheet. Online resource, available at: http://www.arb.ca.gov/toxics/dieseltac/factsht1.pdf Last accessed on August 13, 2004.

U.S. Environmental Protection Agency, Draft Health Assessment Document for Diesel Exhaust, July 2000, EPA/600/8-90/057E.

California Air Resources Board, "Statewide Portable Equipment Registration Program." Online resource, available at: http://www.arb.ca.gov/perp/perp.htm Last accessed on August 13, 2004.

FIGURE 2

National NO_x emissions by source category, 2001 (22.3 million short tons)

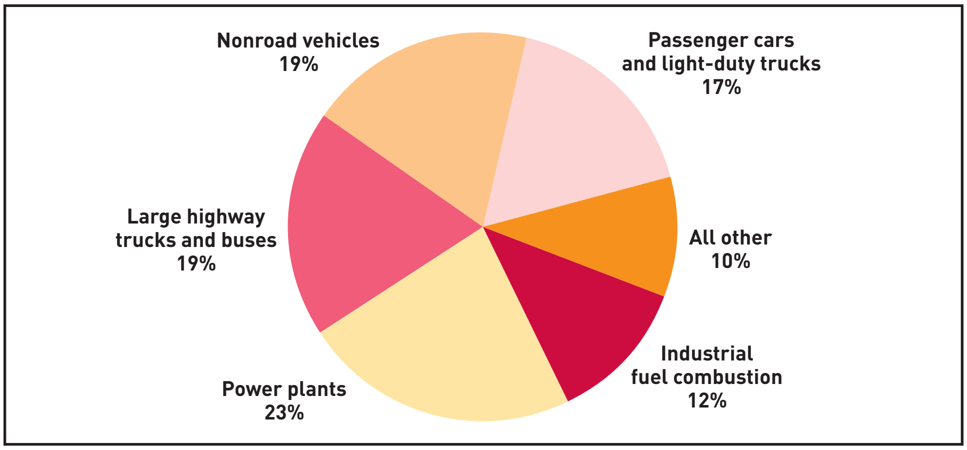
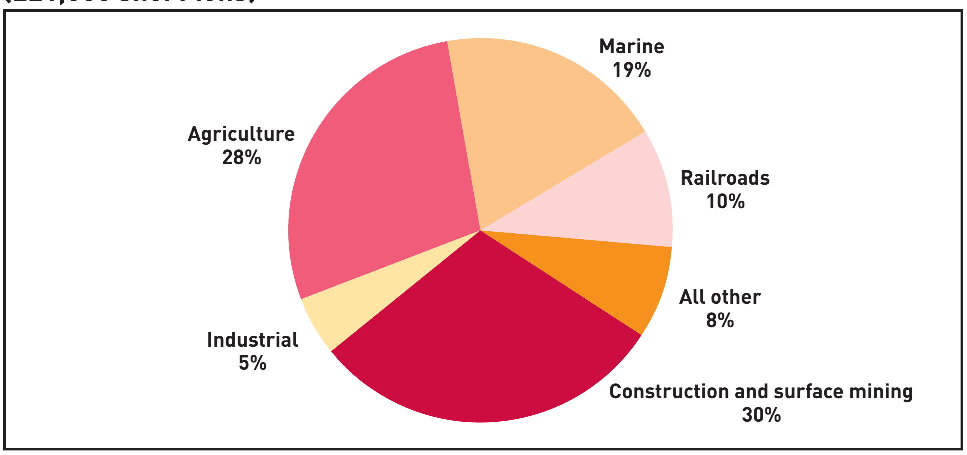


FIGURE 3

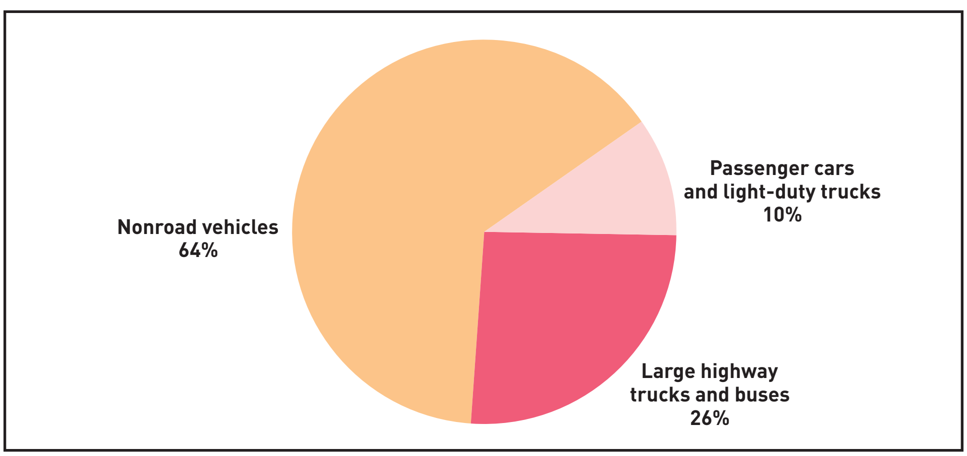
National $PM_{2.5}$ emissions from all nonroad diesel sources, 2001 (221,000 short tons)



Source (Figures 2, 3, 4): National Emission Inventory (NEI): Air Pollutant Emission Trends. 1999 Online resource, available at: http://www.epa.gov/ttn/chief/net/1999inventory.html Last accessed 03/01/05.

FIGURE 4

National $PM_{2.5}$ emissions from all mobile sources, 2001 (452,000 short tons)



CHAPTER 3

Cost-effective ways to reduce health threats

There are many options for reducing pollution from diesel engines in use today. This section describes, first, the "3 R's" for cleaning up diesel engines and, second, behavioral solutions that can help reduce pollution from diesel exhaust. For existing engines, our goal is to substantially reduce pollution today and, as soon as feasible, bring the pollution level down so that it is at least equivalent to the standards for new engines. Until old engines have been replaced with new and regulated technology, these measures are a cost-effective means of reducing diesel pollution.

A systems approach is the most effective way to curb diesel engine pollution. A systems approach takes into account all aspects of engine operations—from fuel type used, to retrofit technologies, to best practices such as anti-idling and proper maintenance practices—all of which are discussed in detail in the next few chapters of the handbook.

Fleet operators should note that, before undertaking any engine modifications, they should determine what effects retrofitting may have on equipment warranties and resolve any issues. Major engine manufacturers have now issued letters and other guidance with respect to warranty implications of cleaner fuels and retrofits, and "in most cases, engine manufacturers will continue to honor engine warranties if emissions control systems are sized, installed and maintained properly."[17]

The "3 R's" for cleaning up diesel engines

The "3 R's" listed below can be used to substantially reduce air pollutant emissions from construction equipment. Environmental Defense strongly encourages combinations of the 3 R's in order to maximize emissions reductions. Neither repowering nor refueling alone can achieve the PM reductions that a retrofit can and, similarly, retrofitting alone cannot achieve the NO_x reductions that many repowers can. Repowering or replacing in addition to retrofitting can maximize reductions in PM and NO_x pollution. In addition, refueling with ULSD fuel can result in even more reductions.

1. REPOWER (OR REPLACE)

One way of ensuring emissions reductions is to replace an entire piece of old construction equipment with a model that meets EPA 2008 standards. Another, less costly, strategy to reduce emissions from older, higher-polluting equipment is the replacement of the in-use engine (i.e., repower) with an emissions-certified engine instead of rebuilding the existing engine to its original specifications. Significant NO_x and PM benefits may be achievable due to the high emissions levels of the uncontrolled engine being replaced.

Depending on the engine and rating of older, higher polluting equipment, average emissions reductions may vary from 25% up to 75%.[18] In some instances, higher emissions reductions may be achievable. For example, replacing a 475 horsepower engine in a MY 1975–1986 Caterpillar 631-D Scraper with a Caterpillar engine meeting EPA Tier One standards[19] would produce a 40% reduction in NO_x and a 62% reduction in PM. Replacing the same engine with one meeting Tier Two standards would produce a 62% reduction in NO_x and an 81% reduction in PM.[20] It is important to note, that while

Environmental Defense strongly encourages repowering where possible, there are significant technical issues that may make it impossible for some older, higher polluting engines (Tier 0 and Tier 1) to be repowered with newer, cleaner engines (Tier 2 and Tier 3).

2. REFUEL

Using alternative fuels or cleaner petroleum-based fuels can also help reduce diesel engine pollution. Alternative fuels are defined in this handbook as any fuel other than petroleum-based fuels such as gasoline or diesel fuel. Emissions reductions can also be achieved by using diesel fuels with very low levels of sulfur, for example ULSD with a maximum sulfur content of 15 parts per million. Fuel emulsifiers, or fuel-borne catalysts are fuel additives that can be added to ULSD to cut emissions even further. In many cases, use of ULSD at 15 parts per million (ppm) of sulfur or less is a prerequisite to effective use of advanced retrofit technologies. Generally, it is not the fuel itself that is "clean", it is the engineered system (i.e. fuel, combustion engineering and exhaust after-treatment). Therefore, to achieve the greatest emissions reductions, a combination of repowered or replaced engines, retrofit technology and cleaner fuels must be used.

3. RETROFIT

"Retrofitting" is incorporating a device into a piece of diesel equipment to reduce pollution.[21] A wide range of pollution-control, or "retrofit" technologies exist today, and can be used in combination with each other and with cleaner fuels to achieve powerful emissions reductions. Different technologies fit different engine operating needs—the key is to select the combination that achieves maximum clean air benefits for a given machine and use.

For example, a retrofit could be a Diesel Particulate Filter (DPF), which traps particles from engine exhaust until the trap becomes loaded to the point that a regeneration cycle is implemented to burn off the trapped particulate matter.[22] DPFs are normally built with a porous ceramic, metal mesh or silicon

A delivery of ultra low sulfur diesel fuel to New York's World Trade Center site. In late 2006, ULSD will be widely available across the United States.

ENVIRONMENTAL DEFENSE

carbide filter housed in a metal container similar to a muffler. However, DPFs are just one of many technologies available to retrofit diesel engines, and many of these technologies serve different in-use functions. There are other examples of retrofit technologies, in addition to more detail about DPFs, in other sections of this handbook.

A combination of clean fuels and retrofits can reduce some hazardous diesel emissions by up to 90%, improving both environmental conditions and public health. Retrofits are remarkably cost-effective when compared to other means of reducing air pollution. For example, the average cost for most applications of a diesel oxidation catalyst (DOC) is approximately $2,500[23] (excluding installation) and for a DPF between $7,000–12,000[24] (excluding installation). The California Air Resources Board estimates that the average cost of retrofitting an engine of 275 horsepower with a catalyzed diesel particulate filter ranges between $6,900–$9,000.[25] By comparison, the average base price for a 200 to 300 horsepower wheel loader is $275,000.[26] Retrofitting an engine with a catalyzed DPF in this price range or with a $2,500 DOC costs only a small fraction (2.5 to 3.2% and less than 1%, respectively) of the cost of replacing the entire vehicle with one that pollutes less.

Moreover, the use of diesel fuel with 15 ppm of sulfur or less can benefit engine operation and maintenance by reducing wear and tear on heavy equipment. This translates into prolonged engine life and less frequent replacement of parts like pistons and cylinder liners.[27] Fleet operators using ULSD may therefore realize a dividend in avoided maintenance.[28] EPA expects these benefits to be equivalent to reducing the cost of the fuel by 3.3 cents per gallon.[29]

Environmental Defense recommends that construction fleet operators who have decided to take steps towards reducing harmful emissions from their construction vehicles contact their Original Equipment Manufacturer (OEM) or other appropriate technology experts to determine the most effective way to reduce diesel emissions from specific machine models in their fleet. Retrofit technology manufacturers and OEMs will probably need information about the fleet in order to advise construction fleet operators on which retrofit solutions will work best for their individual needs. It is always advisable for construction fleet operators to maintain a full inventory of construction machinery (including model and serial number of equipment, year of manufacture, engine displacement, horsepower and serial number of engine, and engine certification for post-1996 engines) working at a given site. This inventory should also include all machinery used to transport debris and construction material to and from a construction site.

Fleet operators who wish to install retrofit technology should also seek information from manufacturers about the proper monitoring, maintenance and operation of retrofit technology.[30] Finally, fleet operators should check with both OEMs and retrofit technology manufacturers about how installing retrofit equipment or using alternative fuels will affect equipment warranties. Most manufacturers have provided guidance to ensure that warranties are not threatened by any use of clean fuels or retrofits.

Equipment management and behavioral solutions to emissions reductions

In addition to the "3 R's" above, there are fleet management and behavioral solutions that can be implemented to reduce pollution. These common sense practices can be implemented immediately and can be a good first step in any retrofitting/diesel emissions reduction plan.

Stop engine idling. Users of heavy-duty diesel equipment (both onroad and nonroad) often keep their engines idling when their equipment is not in use. Reducing or eliminating unnecessary idling can save fuel, and therefore money, as well as reduce emissions. According to EPA, a typical heavy-duty truck or bus can burn approximately one gallon of diesel fuel for each hour it idles, generating significant amounts of pollution, wasting fuel, and causing excessive engine wear.[31] Instead of idling, vehicle owners can purchase small generators or auxiliary power units specifically designed for trucks and buses that provide heat, air conditioning and/or power while a vehicle is not in motion.[32] These devices substantially reduce the fuel consumed and emissions generated during long-duration idling. Many communities across the county have anti-idling rules, but there is a need for enforcement and compliance with these rules and a need to develop and enforce worksite specific rules to govern idling.

Improve equipment maintenance and inspection. Proper maintenance, engine tuning and emissions testing is critical to success. This includes replacing worn out parts, cleaning, tuning and generally maintaining the engine. Whether a retrofit device is installed and/or cleaner fuel is being used, it is always important to ensure that the engine is properly tuned and maintained. This is essential not only for the engines to operate efficiently, but also to ensure that emissions reduction technologies can be used effectively. As with onroad vehicles, nonroad equipment should have regular inspections, including smoke testing. Proper maintenance will ensure complete fuel combustion and as a result PM exhaust is minimized. Proper maintenance can also improve fuel economy and extend engine life.

In addition to reducing idling time and instituting inspection and maintenance programs, the following measures can also help reduce exposure to diesel pollution:

- establishing a staging zone for trucks that are waiting to load or unload material at the work zone in a location where diesel emissions from the trucks will have minimum impact on abutters and the general public; and
- locating construction equipment away from sensitive receptors such as fresh air intakes to buildings, air conditioners and operable windows.

The remainder of this handbook focuses on using cleaner fuel and retrofits to reduce pollution from construction equipment. Reducing pollution from existing nonroad diesel equipment is vital to protecting the public from the health and environmental harms caused by hazardous diesel emissions. Even a relatively new engine can reduce pollution by installing a retrofit and using a cleaner fuel. The goal of these retrofit or emissions control technologies is to reduce emissions, up to and beyond what is required by EPA regulation[33] without negatively impairing the performance of the machine for its intended use.

CHAPTER 4

Successes and regional programs

A variety of regional programs have proven successful at reducing harmful diesel pollution. This section of the handbook provides examples of voluntary government or private sector leadership in retrofitting construction equipment, including: New York City's efforts at the World Trade Center and through Local Law 77, Boston's Big Dig Project, Connecticut's New Haven Harbor Crossing Corridor Improvement Program, the Port of Houston Retrofit Program and retrofits at Washington's Puget Sound. Additionally, this section examines examples of successful economic or market incentive programs that provide financial support for cleaner technologies or fuels, such as the Texas Emissions Reduction Plan, the Carl Moyer Program in California, or the EPA Voluntary Diesel Retrofit Program. The diversity of programs described reflects the varying needs of individual projects with respect to equipment, location, fuel availability and other related factors. When planning a retrofit project, it is always important to take individual situation characteristics into account.

"Best available retrofit technologies": New York City

New York City has demonstrated a strong commitment to reducing pollution from diesel engines. This case study discusses three NYC projects:

- the 7 World Trade Center Diesel Emission Reduction project,
- lower Manhattan redevelopment construction commitments, and
- NYC's Local Law 77.

7 WORLD TRADE CENTER SITE[34]

The Clean Air Communities Diesel Emissions Reduction Project at 7 World Trade Center is the first public-private endeavor of its kind in the city. As former Northeast States for Coordinated Air Use Management (NESCAUM) Executive Director, Ken Colburn stated, "through the application of advanced emission control technology and the use of ultra low sulfur diesel fuel, this Clean Air Communities initiative demonstrates that innovative, clean air progress is possible even at large-scale urban construction sites across the nation."[35]

In October of 2002, the site converted to ULSD for all equipment. Six pieces of construction equipment have already been retrofitted, and one electric crane is being used in lieu of the typical diesel engine crane technology. It is important to note that these strategies target PM, HC, and CO reductions, not NO_x.

LOWER MANHATTAN REDEVELOPMENT[36]

Lower Manhattan is a thriving mix of apartments, art galleries, shops and restaurants. More than 4,000 children live throughout lower Manhattan in neighborhoods as diverse as TriBeCa, Chinatown and Battery Park City. With the rebuilding of the World Trade Center site, lower Manhattan will become one of the nation's largest construction sites, teeming with diesel engines. These engines will be operating just steps from school, playgrounds, parks, homes and offices.

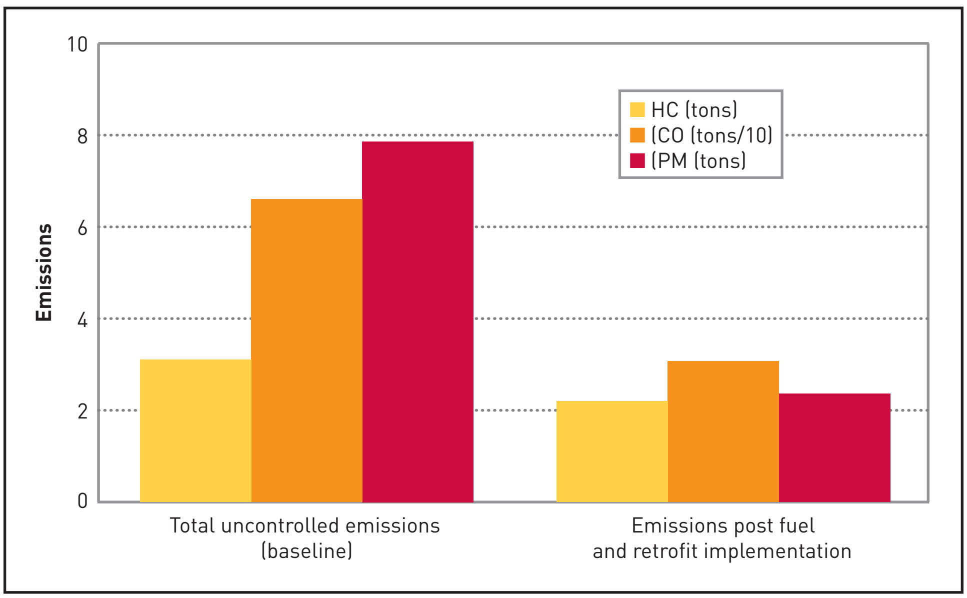
Governor Pataki and New York City have pledged to use the best available retrofits and cleaner diesel fuel in all of the reconstruction efforts. In 2002,

TABLE 3
7 World Trade Center retrofits

Date	Equipment	Retrofit technology
March 2003	Stationary Generator Excavator (CAT 245D, 14.7 l) Excavator (Komatsu PC200, 5.9 l)	DOC DOC DOC
January 2004	Stationary Generator (Rudox, 125 kw, 6.8 l)	Active DPF (Rypos RT500)
May and June 2004	A two-stroke and a four-stroke crane	Metallic High Performance DOC Clean Cat® known by the trade name of "diesel particulate reactors" (by Environmental Solutions Worldwide, Inc.)
Pending	The site has plans to retrofit one more piece of equipment, a concrete pump, with a DOC. Rather than purchasing a new DOC, the retrofit will reuse a high-efficiency DOC from one of the cranes after crane use is finished.	

Source:Information provided by Glenn Goldstein at NESCAUM.

FIGURE 5
Total emissions reductions for 7 World Trade Center project



Courtesy of NESCAUM. Includes emissions from equipment that was not retrofit.

Governor Pataki committed to the use of ULSD and best-available retrofits in all state-controlled lower Manhattan construction projects, including at the World Trade Center site. The New York State Assembly and Senate followed Governor Pataki's lead and passed legislation on June 22, 2004 codifying Governor Pataki's commitment.[37] The law was unanimously approved in both the House and the Senate and was recently signed into effect by the governor.[38] It requires contractors and subcontractors using diesel-powered nonroad vehicles with an engine horsepower rating of 60 HP and above to use only ULSD and to retrofit, where practicable, their equipment with oxidation catalysts, particulate filters or technology with "comparable or better effectiveness."[39]

The pollution reduction efforts at 7 World Trade Center have been paralleled at other redevelopment sites in lower Manhattan. In the PATH reconstruction project, for example, three pieces of construction equipment were chosen for retrofits: a Caterpillar XQ2000 Genset and two Caterpillar 966G TG-22 Loaders. Caterpillar, the original manufacturer of all of the pieces of equipment, was chosen to perform the retrofits.

Caterpillar chose to utilize a passive DPF, the CRT™, manufactured by Johnson Matthey. The CRT™ particulate filter is a patented emissions control technology that contains both a platinum oxidation catalyst and a particulate filter. Caterpillar specifies the minimum exhaust temperature must be at least 260°C for at least 40% of the operating time. Though loaders met these minimum requirements, a detailed engineering analysis on the generator's exhaust temperature found that it was an unsuitable candidate for a DPF. The generator was only being used consistently at approximately 20% of its rate and thus lacked sufficient exhaust temperature.

In August of 2003, H.O. Penn (Caterpillar's local dealership) and Caterpillar design engineers installed the DPFs on the two 966G Loaders. The installation process took eight to ten hours, which was approximately double the expected installation time. This delay can probably be attributed to these retrofits being the first installations of this kind performed by H.O. Penn as well as the need to modify several brackets/components during installation. During the emissions testing, the time required to remove the original muffler and replace it with the DPF was cut in half.

One concern about using DPF technology is failure of the DPF to regenerate, which could lead to excessive engine backpressure. Backpressure must be checked so that it does not increase to levels that may ultimately damage the engine. For this reason, Caterpillar decided to provide an integrated exhaust backpressure alarm with the retrofits to alert the driver if the backpressure is too much. The alarm, mounted in the cab of the loader, is both visual and audible. If a pre-specified backpressure is exceeded for more than a set time interval the alarm lights up.

The installed cost of the DPFs for the wheel loaders was approximately $15,000 each. This cost is probably higher than the future cost of retrofits of this type because this was the first installation on a Caterpillar 966G loader for both Caterpillar and H.O. Penn. After the first few installations, labor efficiencies are typically realized, as evidenced by the decreased installation time from the initial installation to the emissions testing installation. Further, as market demand increases, capital costs are expected to decrease. Additional project costs came from the April 2005 price premium of $0.01–$0.18 per gallon of ULSD in the New York City area. The use of ULSD is not expected to change maintenance schedules or cost, however, using DPFs is expected to slightly increase maintenance responsibilities and cost. Specifically, the filter technology must be cleaned to maintain emissions reduction benefits. A cleaning contract was not negotiated for this project, but other negotiated contract prices in the New York City area range from $300 to $500 per cleaning event. The DPFs have not yet been in service for a year, and have experienced no operational problems.

To establish the emissions reduction potential of the different strategies (ULSD vs. ULSD/DPF), emissions testing was performed using two different types of portable emissions monitoring systems: the Clean Air Technologies

Construction at the World Trade Center site.

ENVIRONMENTAL DEFENSE

International Montana system and the Environment Canada DOES2 system. Emissions testing was conducted for two weeks between September and October of 2003; significant PM emissions reductions were documented. Both monitoring systems identified PM emissions reductions of 15 to 20% for the use of ULSD alone, and of greater than 90% when ULSD was combined with the DPF. Additionally, the use of the DPF also produced significant CO emissions reductions. The switch to ULSD alone produced CO emissions reductions in the range of 1 to 10%, and more than 85% reductions were achieved when the DPF technology was used with ULSD.[40]

NEW YORK CITY LOCAL LAW 77

Recently, New York City committed to emissions reduction measures for all city-funded construction. New York City Local Law 77 calls on New York City to use clean fuels and advanced emissions-control technologies in all city construction fleets and contracts. The law requires two fundamental steps.[41] First, it requires the use of ULSD with a maximum sulfur content of 15 ppm in all city contracts, on a schedule set forth in the law. Second, it requires use of "best available" emissions control technology for any class of engine to which the law applies.

Local Law 77 provides a high standard for what shall constitute best available technology, calling on the City to use technologies that reduce both fine particulate matter (PM) and oxides of nitrogen (NO_x). Specifically, Local Law 77 requires that agencies use technologies that "shall be primarily based on the reduction in emissions of particulate matter and secondarily based upon the reduction in emissions of nitrogen oxides."[42] The DEP recently promulgated rules defining "best available technology."[43]

Retrofits and ULSD have been tested at the 7 World Trade Center site, incorporated into Lower Manhattan Development Corporation design guidelines, and now every Environmental Impact Statement for major reconstruction projects in lower Manhattan, from the Fulton Street transit center to Route

Even private NY contractors have joined the diesel retrofit effort. After Pavarini-McGovern Construction Company was found in violation of a local emissions regulation, they retrofit a 1971 380 HP crane with a DOC and committed to using the fuel-borne catalyst Platinum Plus.

9A, has committed to using advanced retrofits in their environmental impact statements. For example, the Fulton Street Transit Center draft environmental impact statement requires the use of Tier 2 compliant equipment with PM emissions reductions at 85%.[44] Additionally, many projects in lower Manhattan are already moving ahead with emissions-reduction strategies based on a wide range of technologies.

The Big Dig[45]

The Central Artery Project in Boston, also known as the "Big Dig," has built 161 lane miles of highway in a 7.5-mile corridor directly through the middle of densely populated downtown. The project, which began in September 1991 and is currently scheduled to be substantially completed by the end of 2005,[46] presented an historic opportunity to test and demonstrate the feasibility of pollution control retrofits. Use of these retrofits helps to minimize the impact of such a large-scale project by reducing air pollution and lessening the health impact of a major construction project on workers, neighborhoods and regional air quality.

The Massachusetts Turnpike Authority (MTA) in collaboration with the Massachusetts Department of Environmental Protection (DEP) and NESCAUM, chose to retrofit construction equipment with diesel oxidation catalysts. Although other technologies achieve higher particulate reduction rates than DOCs, the MTA preferred DOCs for several reasons—primarily because the very clean diesel fuel (15 ppm of sulfur or less) needed to operate other technologies was not available at the time the Big Dig began.

Retrofit requirements were incorporated into Big Dig construction contracts.

MASSACHUSETTS TURNPIKE AUTHORITY

The Big Dig retrofit project has resulted in the installation of DOCs on approximately 200 pieces of construction equipment—this includes small in-tunnel cranes,[47] lifts, excavators, bulldozers, generators and compressors. This effort will achieve air emissions reductions that are the equivalent of removing 1,300 diesel buses off of Boston streets for a full year.[48]

The Big Dig retrofit project is a true success: **No adverse operational problems or additional maintenance costs have been experienced by Big Dig construction equipment retrofitted with DOCs.**[49] Additionally, preliminary estimates of area-wide emissions reductions from the retrofitted equipment amount to approximately 36 tons per year for carbon monoxide, 12 tons per year of hydrocarbons, and 3 tons per year of PM.[50]

The Massachusetts Highway Department provided funding to contractors to purchase the emissions control devices. According to Alex Kasprak, Environmental Engineer, Massachusetts Turnpike Authority, one of the lessons learned from the Big Dig project is that it is best to include the requirement for emissions control equipment as part of the contract's bid package. By doing so, the cost of the retrofit equipment can be included as part of the overall contract cost. This will also ensure that the maximum number of offroad pieces of equipment can be retrofitted.[51] Overall, the Big Dig retrofit program is now being used as a model by regulatory agencies to encourage other construction projects to utilize retrofitted diesel equipment.[52]

I-95 New Haven Harbor Crossing Corridor Improvement (NHCC Project)[53]

Eighty-three diesel oxidation catalysts have successfully been installed at the Connecticut NHCC project. In addition, construction contractors have volunteered to use low sulfur diesel (500 ppm sulfur content) on all their nonroad equipment. The NHCC project is part of Connecticut's Clean Air Construction Initiative and was launched to protect laborers as well as residents from harmful construction emissions along a densely populated corridor. Construction began in 2001.

The Connecticut Clean Air Initiative was a mutual effort of the Connecticut Department of Transportation (ConnDOT), the Connecticut Department of Environmental Protection, the Connecticut Department of Motor Vehicles, and the Connecticut Construction Industry Association to come up with real-world solutions to air quality problems. With compromise, a contract specification was evolved from the above mentioned agencies to improve the quality of life through this long duration construction project.

ConnDOT is requiring all contractors and subcontractors to take part in the Connecticut Clean Air Construction Initiative. The cost to purchase the DOCs and the cleaner fuels was included in the overall contract cost, as bid by each contractor. At present, all contractors have decided to install DOCs. Although other technologies achieve higher particulate reduction rates than DOCs, they were preferred primarily because low sulfur diesel fuel

"The Big Dig diesel construction retrofit program has proven that retrofitting construction equipment with DOCs is very feasible, and provides beneficial air quality improvements in terms of emission reduction and odor control."

—Alex Kasprak, Environmental Engineer, Massachusetts Turnpike Authority, CA/T Project

"I am very proud of Connecticut's success in this Clean Air Construction Initiative. The State of Connecticut's various Departments and the Connecticut Construction Industry Association (CCIA) worked and are still working to benefit the people of Connecticut by trying to improve the quality of life in locations where transportation projects are occurring. We are sensitive to those that live or work in an area were construction is going on, day after day, and how it affects those people's lives. This Initiative is a step in the right direction. As technologies improve, greater air quality can be achieved."

—Donna Weaver, Transportation Planner, Office of Environmental Planning, Connecticut Department of Transportation

(500 ppm sulfur content), rather than the ULSD (15 ppm of sulfur or less) needed to operate other technologies, was used for the project. Estimates for reduced emissions from the program are 20 tons per year for carbon monoxide, 2 tons per year for fine particulate matter (with clean fuels or oxidation catalysts) and 8 tons per year for hydrocarbons (with oxidation catalysts only).[54]

Because of the success of the Connecticut Clean Air Initiative on ConnDOT projects, other agencies such as the Connecticut Department of Public Works and the Connecticut Department of Economic and Community Development are also requiring their construction contractors to follow the ConnDOT specification. Three or four diesel oxidation catalysts have been installed on two projects as a result.

Port of Houston[55]

The Port of Houston is the sixth largest port in the world,[56] and a significant contributor to NO_x emissions in the eight counties of the Houston-Galveston area. All eight counties in this region fail to comply with EPA's health-based eight-hour ozone standards.[57] Although the Port of Houston Authority is not the largest contributor to emissions in the area, they have become the region's leader in emissions reduction activities and commitments.

Through demonstration testing of the alternative fuel PuriNOx™ on rubber-tire gantry crane with a 550 horse-power engine, the Port of Houston Authority (PHA) has reduced NO_x emissions by 25% and PM emissions by 50%.[58] In September of 2003, the Port Authority converted 39 yard tractors and yard cranes to PuriNOx and enacted the requirement that any new equipment purchased be able to use the technology.[59] Approximately 49 pieces of cargo-handling equipment are currently operating on PuriNOx for a NO_x emissions reduction of approximately 21 tons per year at a total cost of $216,000. According to Roger Guenther, container facilities manager at Barbours Cut Container Terminal, "It's just a different fuel, nothing special has to be done to the equipment. I could put diesel back in any of the offroad vehicles and they would run just fine. I can't tell any difference from one to the other."[60]

The PHA also applied for and received $337,000 in state funding (see the Texas Emissions Reduction Program section below) to replace two Fireboat FARNSWORTH propulsion engines with engines that produced 5.6 tons less NO_x per year.[61] Additionally, the PHA has purchased several new yard tractors and container handlers with clean engine technology, resulting in NO_x emissions reductions of 6.9 tons per year at a cost of $21,500.[62] Further, the PHA purchased 33 ultra-low emissions vehicles or propane vehicles for their onroad fleet.[63] The PHA plans to extend its retrofit program (which involves either retrofitting vehicles with oxidation catalysts,

PORT AUTHORITY OF HOUSTON

New equipment purchased by the Port of Houston Authority must run on PuriNox, an alternative fuel that reduces NO_x emissions.

switching their fuel use to PuriNOx, or both) to between 50 and 250 vehicles.[64] In total, the PHA has reduced NO_x emissions by 33.5 tons per year with the assistance of $574,000 in TERP funding.

Puget Sound in Washington[65]

Washington State's Puget Sound Clean Air Agency has formed a coalition, known as Diesel Solutions®, to dramatically reduce diesel engine pollution in the region. The first step in this program was to work with Conoco/Phillips and U.S. Oil to ensure that ULSD was locally available. Since ULSD was made available, 800 school buses have been retrofit, mostly with DOCs.

Approximately two dozen pilot projects used DPFs for the retrofits. The average retrofit cost has been between $1,200 and $8,000 per vehicle, and projects are financed through a statewide retrofit program developed as part of the EPA Voluntary Diesel Retrofit Program. The next step in the program is to retrofit diesel engine construction equipment with pollution control technology. As part of this effort, the Puget Sound Clean Air Agency has requested retrofits in their comments on local project environmental impact statements, and has been speaking with a number of construction companies.[66]

The Texas Emissions Reduction Program[67]

In 2001, the Texas State Legislature established the Texas Emissions Reduction Program, enacted through Senate Bill (SB) 5. The goals of the TERP, as stated in SB 5, are to: "assure that the air in the state is safe to breathe and meets minimum federal standards established under the Federal Clean Air Act (42. U.S.C. Section 4707); develop multi-pollutant approaches to solving the state's environmental problems; and adequately fund research and development that will make the state a leader in new technologies that can solve the state's environmental problems while creating new business and industry in the state."[68]

The TERP covers 41 counties in the state where air quality violates or is close to violating EPA standards.[69] Projects are eligible for financial assistance through a number of programs, including: the Emissions Reduction Initiative Grants Program, which offers incremental funding for NO_x emissions reduction activities; the Small Business Program, which offers grants to small businesses for pollution reduction measures; the Heavy-Duty Motor Vehicle Purchase or Lease Incentive Program, which allows the Texas Commission on Environmental Quality to reimburse a purchaser or lessee of a new onroad heavy-duty vehicle for the difference in price between that vehicle or a higher-emitting diesel-powered vehicle; and the Light-Duty Motor Vehicle Purchase or Lease Incentive Program, which (though currently unfunded) is intended to provide financial incentives for the purchase of light-duty motor vehicles that are EPA-certified at a lower NO_x emissions standard than regular light-duty motor vehicles.

TERP will offer a total of approximately $130 million in funding for emissions reductions programs each year over the next three years.[70]

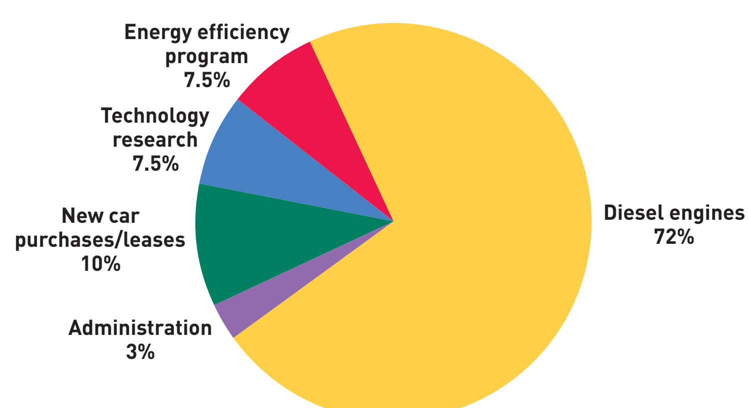
In the 2004 grant application period, the Texas Commission on Environmental Quality had approximately $127.5 million available for grant programs. Eligible projects include new purchases, replacements, retrofits, repowers, and refueling projects.[71] The projects from the first round of grants are expected to reduce NO_x emissions by over 3,500 tons over their lifetime, at an average cost of about $5,175 per ton reduction.[72] The projects funded by the second round of these grants are expected to reduce NO_x emissions by almost 13,600 tons over the life of the projects, at an average cost of $5,960 per ton reduction.[73] In 2004, the average cost per ton reduction of NO_x emissions was approximately $5,800. This represents a lower average cost per ton NO_x emissions reduction than achieved by 2002-2003 grants funds, which offered over $28 million in funding to reduce NO_x emissions by over 4,100 tons over the life of the projects at an average cost of approximately $8,362 per ton.[74] The Emissions Reduction Grant Incentive Program NO_x cost-effective criteria will be capped at $7,000 per ton reduction in 2005.[75] Grant award details are available at: http://www.tnrcc.state.tx.us/oprd/sips/terp.html and more information can be found at: http://www.tnrcc.state.tx.us/oprd/sips/terp.html.

California's Carl Moyer Program[76]

The Carl Moyer Memorial Air Quality Standards Attainment Program

FIGURE 6

TERP funding distribution, 2001 (approximately $130 million)



When the Texas Emissions Reduction Plan is fully implemented, the majority of funds will go toward replacing older diesel engines with cleaner-burning models.

Source: TNRCC. "Clean Air Incentives." Natural Outlook, Fall 2001. Online resource, available at: http://www.tceq.state.tx.us/assets/public/comm_exec/pubs/pd/020/01-04/clean_air.pdf Last accessed 04/12/05.

provides funds on an incentive basis for the incremental cost of cleaner than required engines and equipment. Funding is available for nonroad equipment 50 hp or greater. Eligible projects include cleaner onroad, offroad, marine, locomotive and stationary agricultural pump engines, as well as forklifts, airport ground support equipment, and auxiliary power units. The program achieves near-term reductions in NO_x emissions, which are necessary for California to meet its clean air commitments under the State Implementation Plan. In addition, local air districts use these NO_x emissions reductions to meet commitments in their conformity plans, thus preventing the loss of federal funding for local areas throughout California. The program also seeks to reduce particulate matter (PM) and hydrocarbons.

The California Air Resources Board (CARB) is responsible for the development and oversight of the majority of the Carl Moyer Program. CARB distributes Carl Moyer funding to California's 35 local air districts, which then screen applications and distribute the funding to diesel engine owners. The program has provided grants for projects such as repowering nonroad equipment, agricultural irrigation pumps, sweepers, tractors and marine vessels. It has also helped to fund the purchase of new natural gas refuse trucks and buses.

Governor Schwarzenegger recently signed AB923, which authorized increasing motor vehicle registration fees and tire fees to support programs, such as the Carl Moyer Program, that reduce air pollution. Through year six of the Carl Moyer Program, it had received approximately $154 million dollars in total funding.[77] With its recent reauthorization, up to $140 million a year of incentive funding is available for air pollution mitigation technologies.[78] More information is available on the Carl Moyer Program web site at: http://www.arb.ca.gov/msprog/moyer/moyer.htm.

The EPA Voluntary Diesel Retrofit Program

The Environmental Protection Agency, through the Office of Transportation and Air Quality, has developed a program to encourage voluntary diesel retrofits. This program uses economic incentives, which can be applied at the federal, regional, state, and local levels, to produce emissions reductions through the use of pollution control technology. One tool used by this program is grants, which have been awarded to various parties to help fund the cost of retrofit projects. Information on recent grants is available on the EPA Voluntary Diesel Retrofit Program web site.

EPA is also in the process of developing a policy to allow diesel engine retrofits to count as credits that can be traded or used to offset stationary source emissions. As a corollary to this program, EPA has developed a verification program to ensure that pollution control technology providers advertised emissions reductions. More information on the EPA verification process is available in the "Onroad and Nonroad EPA/CARB Verification" section of this handbook. Further information on the Voluntary Diesel Retrofit Program, verified technologies, and financial incentives for the use of pollution control technology can be found on the EPA Voluntary Diesel Retrofit web site, at: http://www.epa.gov/otaq/retrofit/index.htm.

Fueling a cleaner tomorrow

Ultra-low sulfur diesel fuel (ULSD)

The sulfur in diesel fuel directly contributes to the amount of pollution emitted, such as engine-out PM emissions[79] and secondary emissions of SO_4.[80] Currently, the EPA standard for onroad diesel fuel is 500 ppm (also referred to as No. 2 Diesel). The current nonroad standard for diesel fuel is 5,000 ppm, but sulfur levels are generally around 3,400 ppm. As of September 2006, 15 ppm sulfur content (ULSD) will become mandatory for all onroad diesel engines[81] and in 2010, 15 ppm sulfur content fuel will become mandatory for many nonroad engines.[82]

Because ULSD is not required nationally until September 2006, its current availability and costs vary depending on location, whether ULSD has to be specially trucked in for a project, and the quantities needed. The map below shows areas within a 250-mile radius of where ULSD is refined,[83] or areas where ULSD should be available as of August 2004. Once ULSD becomes mandatory for the onroad sector in 2006, it will be readily available across the United States and cost differentials between low sulfur diesel (500 ppm) and ULSD should be minimal.

ULSD reduces harmful emissions, allows for aggressive retrofit devices, and reduces maintenance costs. EPA states: "While the estimated added cost for low-sulfur fuel is about seven cents per gallon, the net cost is projected to average about four cents per gallon because the use of ULSD could significantly reduce engine maintenance expenses."[84] The maintenance dividend for low sulfur fuel in large onroad vehicles (e.g. trucks and buses) is about $600 over the life of the engine or a fuel cost savings of about 1 cent per gallon.[85] The cost savings for nonroad equipment may be higher, because baseline sulfur levels in nonroad fuel are up to six times higher than onroad fuel.

The program has been a tremendous success. In the short period from October 1, 2004 to February 1, 2005, the Lane Clean Diesel Project received commitments from its partners to purchase over 2 million gallons of ULSD.

By switching from onroad diesel fuel (500 ppm) or from nonroad diesel fuel (about 2000 ppm-3000 ppm) to ULSD, particulate matter, smoke and sulfate emissions will be reduced.[86] ULSD used in combination with advanced retrofit technology allows for dramatic reductions of up to 90% of the PM, HC and CO found in diesel exhaust. Those who wish to design a retrofit program should talk with local fuel providers to determine whether ULSD is available in their market, and if it is not yet available, the timeline within which it will be

An Oregon success story

Sharon Banks of the Lane Regional Air Pollution Authority (LRAPA), Oregon successfully built a market for ULSD fuel in Lane County, Oregon. The objective was to bring ULSD fuel to Lane County at an affordable price ahead of the September 2006 mandate.

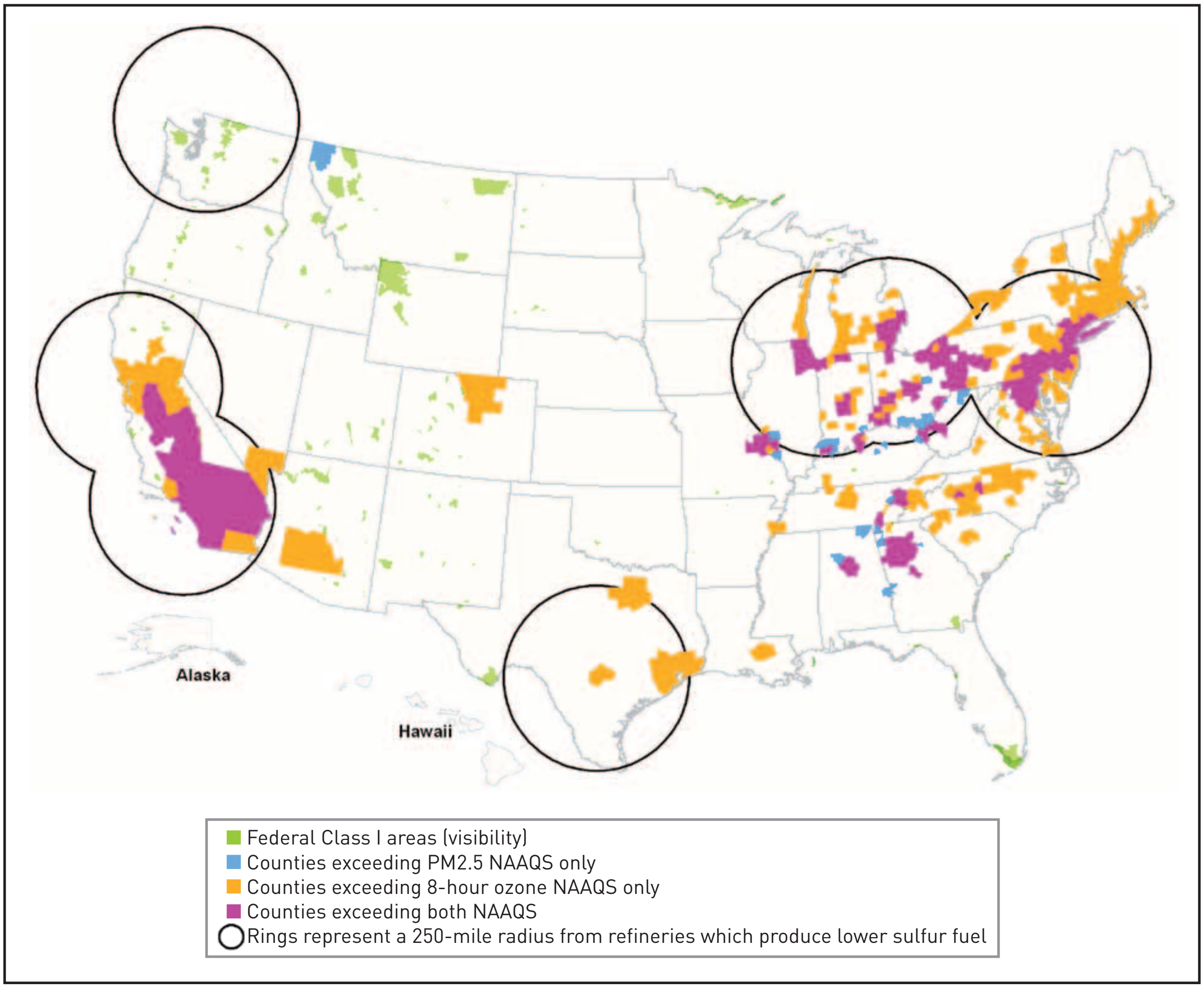
To bring the price of ULSD fuel down to a competitive level, Ms. Banks built enough demand in Lane County to make ULSD fuel attractive to users. City managers, County administrators, school districts, transit authorities, municipal waste haulers, large private fleets, fuel distributors and public utilities were all involved in the endeavor.

available. EPA rules mandate that all new onroad diesel vehicles use ULSD by 2006, at which point the fuel will be widely available nationwide.[87] New EPA rules do not require the use of ULSD in the nonroad sector before 2010, but the widespread availability of the fuel by September 2006 makes it easy for any nonroad fleet to begin using the fuel ahead of the EPA nonroad schedule.[88]

Emulsified diesel fuel

Emulsified diesel fuel is diesel fuel (LSD or ULSD) blended with up to 20% water and a proprietary additive. The water emulsion has to be stirred regularly when kept in a stationary tank to ensure that the water molecules are completely enclosed by fuel molecules. Stirring is important to avoid separation, which could cause engine corrosion and decreased lubricity. Storage tanks can be equipped with stirring devices such as circulation pumps. Though the timeframe for recirculation needs may vary based on individual product specifications, Lubrizol's PuriNOx can be stored at room temperature

FIGURE 7
Ultra low sulfur diesel fuels availability



Source: http://www.epa.gov/otaq/retrofit/fuelsmap.htm for 3–4 weeks before recirculation becomes necessary.[89]

Emulsified diesel fuels generally do not require engine modifications. However, fleet operators should check with OEMs before using a fill-and-go system like emulsified diesel and fleet operators should confirm warranty compatibility with the equipment/engine manufacturer before using emulsified fuels. Emulsified fuels have been tested for many onroad and nonroad diesel engines, although only Lubrizol's PuriNOx summer blend has received EPA verification. Summer blend PuriNOx cannot be used when ambient temperatures fall below 20 degrees Fahrenheit.[90] EPA has verified PuriNOx for both on and nonroad use and has confirmed a 16.8–23.3% reduction in PM and a 17–20.2% reduction in NO_x for nonroad applications.[91]

CARB has verified PuriNOx for onroad engines model years 1988-2003 at 50% PM (Level 2) reduction and 15% NO_x reduction.[92] In addition, CARB has verified PuriNOx and AZ Purimuffler or AZ Purifier System for 1996 through 2002 diesel engines used in off-road applications specifically at the ports, railway yards and other intermodal/freight handling operation applications only. The PuriNOx and AZ Purimuffler or AZ Purifier System uses a diesel oxidation catalyst and an emulsified diesel fuel to achieve a 50% reduction in PM emissions, qualifying it for a Level 2 CARB verification. The system also achieves a 20% reduction in NO_x emissions.[93]

Using retrofit technology in conjunction with emulsified fuels significantly reduces both PM and NO_x. For example, use of an emulsified fuel with a DPF produces PM emissions reductions of 95%, HC reductions of 85%, CO reductions of 75% and NO_x reductions of 25%. Use of emulsified diesel fuel in conjunction with a DOC produces PM emissions reductions of 65%, HC reductions of 60%, CO reductions of 70% and NO_x reductions of 25%.[94] Thus, Environmental Defense recommends that if emulsified fuel is used, it be used in conjunction with a retrofit device whenever possible to maximize emissions reductions.

While many applications have been successful, some have raised concerns regarding fuel separation in equipment that is not being used regularly, loss of power, slower hydraulic movement, injector pump failure in newer engines and acceleration.[95] When considering the emissions reduction rates of emulsified fuel, possible loss of engine power and fuel efficiency should be taken into consideration. Fuel efficiency depends highly on the duty cycle, and Lubrizol reports that a typical loss is between 5 and 10%.[96] Since water does not contribute energy, emulsified diesel fuel can decrease engine power by approximately 10–13%[97] depending on how much water has been added.[98] Engine power is also highly dependent on the duty cycle and current engine sizing of the vehicle. PuriNOx has successfully been used in a variety of both low and high horsepower offroad engines, from small little John Deere Gators (all terrain vehicles) to tractors, loaders, scalars, dozers, haul trucks, cranes, marine vessels, etc.[99]

Availability and cost of emulsified fuel should be addressed with the local fuel distributor. If a centralized fuel storage tank is available on site, the emulsified fuel can be blended on site, which may be less expensive than when it has to be trucked in. According to Lubrizol, for example, PuriNOx prices vary by distributor, but a good approximation of cost nationwide is $0.25 per gallon over diesel fuel.[100] However, depending on where PuriNOx is sold and depending on the price of regular diesel fuel, it can also be the same price or less expensive than regular diesel fuel.[101]

Fuel-borne catalyst

A fuel-borne catalyst (FBC) is a liquid fuel additive that conditions diesel fuel, improving combustion and reducing emissions. An FBC can either be added to bulk fuel or directly to the construction vehicle's fuel tank. An FBC typically contains small amounts of precious metals such as platinum, cerium, or iron compounds. Use of an FBC product can also improve fuel economy by up to 10% and increase horsepower by up to 5%.[102]

EPA has verified only one FBC, called Platinum Plus®, so far.[103] EPA verified reduction rates for the FBC used in conjunction with a DOC are 25-50% for PM, 16-50% for CO and 0–5% for NOx. According to Platinum Plus' manufacturer, only about 2% of the platinum gets into the environment because the platinum bonds with the hot surfaces of the engine.[104] Platinum in the environment has a limited potential to produce allergy-like symptoms for sensitive populations, such as: conjunctivitis, coughing, wheezing or asthma attacks.[105] However, a recent study by the United Kingdom's Committee on Toxicity of Chemicals in Food, Consumer Products, and the Environment reported: "platinum emissions from the platinum based fuel catalyst were unlikely to be in an allergenic form."[106]

To address the amount of platinum released into the environment and to achieve the maximum possible emissions reductions, Environmental Defense recommends that an FBC be used in conjunction with retrofit equipment, such as a DPF or the catalyzed wire mesh filter mentioned in the technology section.[107]

Alternative fuels

To reduce emissions of hazardous pollutants, construction fleet operators can use an alternative fuel. The use of alternative fuels provides not only environmental benefits, but also can reduce dependency on foreign petroleum and improve energy security through supply diversification. As with all vehicles and equipment, to achieve the maximum possible environmental benefits, alternatively fueled vehicles must be properly maintained.

This section of the handbook explores the specific advantages of biodiesel, compressed natural gas, liquefied natural gas and propane fuels. It is important to note that alternative fuels might be right for some fleets but not for others, especially because, at this time, alternative fuels do not have the same easily accessible infrastructure that diesel fuel does. Information on the availability of these, and other, alternative fuels is available from the Department of Energy's Alternative Fuels Data Center, which can be accessed online at: http://afdcmap.nrel.gov/locator/LocatePane.asp.

Additionally, federal and state tax incentives may be available to help defray increased purchasing costs for alternative fuel vehicles. More information on tax and other financial incentives for alternative fuel use is available from the Department of Energy's Alternative Fuels Data Center at: http://www.eere.energy.gov/cleancities/afdc/laws/incen_laws.html.

BIODIESEL

Biodiesel is a renewable, biodegradable, low-sulfur fuel that is produced from many types of feedstocks including vegetable oils (soybeans, rapeseeds, canola oil) or animal fat. Biodiesel is high in oxygen content (oxygenates) which leads to lower PM emissions.

Typically, biodiesel is blended with conventional diesel in a 20% biodiesel to 80% conventional diesel solution (B20). At B20, most of the potential PM benefits have been achieved while minimizing potential NO_x emissions increases. Biodiesel can also be blended with ULSD fuel, and in fact, makes up for ULSD's low lubricity. For example, using a 1% biodiesel and 99% ULSD blend increases lubricity 65% over pure ULSD, which is essentially equivalent to regular diesel fuel.[108]

EPA has statistically determined that PM, HC and CO emissions decrease and NO_x emissions increase slightly with B20 mixtures, when compared with conventional diesel. B20 increases NO_x by about 2%, decreases PM by approximately 10%, decreases HC by around 21% and decreases CO by approximately 11%.[109] Thus, biodiesel helps decrease emissions of some air pollutants, but it slightly increases NO_x emissions.[110] Due to the slight NO_x increase, biodiesel may only be appropriate for use in areas that are attaining the public health based standards for ozone—and even then, only in combination with other NO_x reduction strategies. B20 may also be appropriate for areas that have achieved their air quality standards but must work actively to maintain that status (maintenance areas).[111]

Biodiesel may also be used alone (B100) rather than blended with conventional or ULSD fuel. EPA has verified Biodiesel blends ranging from B1 to B100 for use in voluntary retrofit initiatives.[112] According to EPA, B100 is 5–11% less fuel efficient than conventional diesel.[113] Specifically, B100 reduces emissions of hydrocarbons by an average of 67%, carbon monoxide by an average of 48%, and particulate matter by an average of 47%.[114] On average, B100 emits about 10% more NO_x than conventional diesel fuels do.[115]

COMPRESSED NATURAL GAS AND LIQUEFIED NATURAL GAS

Compressed natural gas (CNG) is a colorless, tasteless, and non-toxic fuel that is mostly derived from methane. Although naturally odorless, an odorant is frequently added to CNG supplies to warn of its presence, a precaution made necessary by its flammability.[116] CNG is extracted from extensive underground reserves in gas wells or in conjunction with crude oil production and is commonly used to power water heaters, stoves, and laundry machines. However, CNG's utility is not limited to the household—it can also be an excellent and clean alternative fuel for mobile sources and has been used in the heavy-duty onroad sector.[117]

The U.S. Department of Energy describes CNG as "clean burning" producing significantly fewer harmful emissions than reformulated gasoline or diesel when used in natural gas vehicles. According to the U.S. Department of Energy, commercially available medium- and heavy-duty natural gas engines have demonstrated over 90% reductions of CO and PM and more than 50% reduction in NO_x relative to commercial diesel engines.[118] To use CNG, one must purchase a vehicle designed specifically for CNG use. At this time, CNG is not commercially available for nonroad use, although several hand-built demonstration units exist.

Liquefied natural gas (LNG) is natural gas that has been cooled to temperatures of 260 degrees below zero, but it is typically kept at high pressure so that it does not have to be so cold. The fuel's freezing temperatures increase the need for safety training by those operating LNG fueled vehicles. Skin contact with the fuel must be avoided, and machines that use LNG can vent a flammable gas mixture when not in use and parked indoors. Additionally, LNG must be used in a context where the LNG facility or terminal meets all applicable state or local government safety and siting rules. Similar to compressed natural gas, LNG has been used in the heavy-duty onroad sector,[119] but is not commercially available for the nonroad sector at this time.

PROPANE

Propane, known also as Liquefied Petroleum Gas, is a colorless and non-toxic fuel produced as a byproduct of natural gas processing or crude oil refining. Application of moderate pressure can convert the gas into a liquid, increasing the ease with which it is stored and transported. Although propane is less fuel efficient than gasoline, its higher octane rating means that engines run more smoothly and efficiently. Propane also produces less pollution than gasoline, and it can lower carbon dioxide, carbon monoxide and non-methane hydrocarbon emissions.[120] Additionally, propane is readily available—fueling stations are found in all 50 states. This fuel is widely used in the onroad sector, and has been successfully used by non-road vehicles such as fork-lifts or loaders.[121]

According to the U.S. Department of Energy, propane vehicles can produce fewer ozone-forming emissions than vehicles powered by reformulated gasoline. In addition, tests on light-duty, bi-fuel vehicles have demonstrated a 98% reduction in the emissions of toxics, including benzene, 1,3 butadiene, formaldehyde, and acetaldehyde, when the vehicles were running on propane rather than gasoline.[122]

CHAPTER 6
Filtering out pollutants

One of the most effective ways to reduce diesel pollution from existing equipment is to combine the cleaner fuels, discussed previously, with retrofit technology. In this handbook, the term *retrofit* is defined as incorporating any device into diesel equipment to reduce pollution. The term *retrofit technology* is used interchangeably with *emissions control technology*, *pollution control technology* and/or *after-treatment technology*.

There are a variety of demonstrated retrofit technologies available to significantly reduce PM, HC, CO, NO_x, toxics and odor emissions from existing heavy-duty diesel vehicles. Many technologies to reduce diesel PM are commercially available today and have been used for more than 25 years on nonroad diesel engines in construction equipment.[123] A number of NO_x control technologies that can significantly reduce pollution are still in development, although some are currently available.[124] Additionally, companies are making substantial investments to develop and commercialize diesel exhaust emissions control technologies. In fact, just 12 of the over 40 member companies that make up the Manufacturers of Emission Controls Association (MECA) have invested more than $1.8 *billion* in R&D and capital expenditures to help reduce pollution from the onroad and offroad diesel sectors.[125]

Thus, available retrofit technologies and applications are expanding rapidly and the industry is working aggressively to pursue solutions to address heavy-duty diesel emissions control.[126] Hundreds of scientists and engineers across the country are contributing to key developments to speed the evolution of diesel emissions control technology[127] and EPA has already formed partnerships with state, local and industry stakeholders in numerous states and the District of Columbia to reduce pollution from existing diesel engines.[128]

This part of the handbook introduces some of the many different options available for retrofitting.[129] It also provides information on the verification status of each technology:

- *Verified* means that the technology has been approved for use in either the onroad or the nonroad sector by the Environmental Protection Agency or the California Air Resources Board;
- *In development* means that the technology has not yet been verified, but may currently be in use in the onroad or nonroad sector, undergoing field testing, or in development.

Retrofit technologies can be geared towards PM or NO_x reduction, though many also reduce CO and HC emissions as well. Most advanced pollution control technologies require diesel fuels with very low levels of sulfur (15 parts per million of sulfur or less) to work properly and many can be combined for even deeper pollution cuts. Please talk to your fleet managers and Original Equipment Manufacturers (OEM) to determine the best options to meet your air quality goals.

Particulate matter reduction

DIESEL PARTICULATE FILTERS (VERIFIED)[130]

A diesel particulate filter (DPF) is an emissions control technology that traps diesel particulate matter from engine exhaust until the trap becomes loaded to the point that a regeneration cycle is implemented to

DPF in-use reduction numbers

NO_x	0%
PM	Up to 90%
HC	Up to 90%
CO	Up to 90%

burn off the trapped particulate matter.[131] DPFs are normally built with a porous ceramic and metal mesh or silicon carbide filter housed in a metal container similar to a muffler. There are two main categories of DPFs: active and passive. The difference between the two is in the methods used to regenerate the filters. Passive systems rely on a catalyst to lower the temperature at which the collected soot will burn and, therefore, rely solely on the duty-cycle of the vehicle and resulting exhaust gas temperatures to ensure that regeneration occurs as frequently as required. Active systems use supplemental heat to supply the necessary energy to burn the collected particulate matter. The heat is provided by either onboard or offboard burners or electrical heaters. The type of DPF suitable for a specific application depends, in addition to other factors, upon the exhaust gas temperature, the daily duty cycle of the subject construction equipment and the availability of ULSD. Passive DPFs require the use of ULSD fuel to facilitate regeneration and prevent catalyst poisoning that would render them inoperable.[132] Active DPFs do not require ULSD fuel.

Active filter systems can be used on a broader range of vehicles because regeneration is accomplished by supplemental means that do not rely on the operation of the vehicle and the resulting duty-cycle. However, an active system can cost more than a passive system.

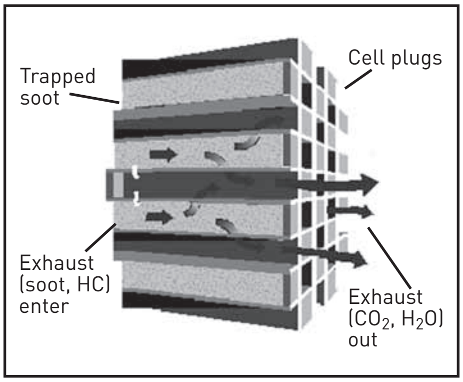
Although DPFs work by forcing the exhaust through porous walls, PM is collected without obstructing the flow of exhaust gases or damaging the engine or vehicle. Diesel particulate filters can reduce $PM_{2.5}$, PM_{10}, HC, and CO emissions by up to 90% and significantly reduce emissions of other toxics, including aldehydes.[133] However, DPFs do not remove NO_x.

Prior to installing DPFs, engines must be data-logged to ensure timely and consistent regeneration and tested to determine whether the required exhaust gas temperature is achievable for the necessary amount of time during the daily duty cycle. In addition, a back-pressure monitor must also be installed

Construction equipment retrofit with a diesel particulate filter.

COURTESY OF JOHNSON MATTHEY

FIGURE 8
Schematic of a diesel particulate filter



MECA, "Minimizing NO2 Emissions from Catalyst-Based Diesel Particulate Filters." IDRAC Meeting, February 6, 2002. Online resource, available at: http://www.arb.ca.gov/diesel/presentations/020602/mecano2resolution.pdf Last accessed 03/03/05

to allow real-time monitoring of DPF performance and to ensure consistent in-use regeneration. If there is insufficient regeneration, the DPF will become plugged with soot, increasing exhaust gas backpressure levels beyond engine manufacturer specifications.

Particulate filters can be installed on new or existing equipment, sometimes as muffler replacements, to trap particulate matter in the exhaust.[134] Because DPFs tend to be larger and heavier than a diesel oxidation catalyst or a regular muffler, DPFs require some engineering to be properly installed on construction equipment. Installation of a DPF is more complex, time consuming and costly than the installation of a DOC. However, the installation of a DPF is worthwhile, because DPFs reduce PM, HC, and CO by up to 90%, whereas DOCs only reduce PM by approximately 20–30%, and HC and CO by approximately 50–70%. According to retrofit manufacturers, installation of a DPF takes about 5–7 hours and a DOC can be installed by the equipment operator in about 1–2 hours.

Depending on the application and size of the equipment, most DPF applications cost between $7,000 and $12,000 excluding installation.[135] Because DPFs are currently more effective at reducing particulate matter than other technologies, Environmental Defense strongly encourages the use of DPFs whenever possible.

Although DPFs are not as common as DOCs, an increasing number of DPFs are already being used at a number of construction sites. Worldwide, DPFs have been installed on over 70,000 heavy-duty vehicles, primarily trucks and buses.[136] Over 20,000 DPFs have been installed on nonroad engines worldwide.[137]

PASSIVE DIESEL PARTICULATE FILTER (VERIFIED)[138]

There are two different types of passive DPFs: catalyzed and regular. A catalyzed DPF will remove the soluble organic

TABLE 4
Examples of nonroad DPF installations

Type of equipment	Type of DPF	Location
Generator (600 kw)	Active DPF (by Rypos)	World Trade Center 7, NYC
Wheel Loader (CAT966)	Passive DPF (by Johnson Matthey)	World Trade Center 7, NYC
Wheel Loader (CAT 966GII)	Passive DPF (by Johnson Matthey)	American Asphalt, CA
Dump Trucks (Cummins, CAT and ITEC engines)	Passive DPF (by Johnson Matthey)	LA and surrounding areas, Seattle, Riverside County, San Diego

fraction (SOF) portion of the PM emissions in addition to regenerating the elemental carbon (soot) fraction of the PM.[139] In addition, the exhaust gas temperature required to ensure proper regeneration is slightly lower for the catalyzed passive DPF than for the regular passive DPF. The catalyzed DPF requires a temperature of approximately 210°C, depending on the catalyst used. The catalyst can also be added to the fuel as a fuel-borne catalyst. CARB staff has evaluated the catalyzed DPF as the most effective control technology because it can reduce PM emissions by over 85%.[140]

A regular DPF typically requires a greater than 260–320°C operating temperature for a significant portion of the duty cycle and has found limited application because of this.[141] If the necessary exhaust gas temperature cannot be achieved for the required portion of the daily duty cycle, an active DPF (see below) should be considered.

ACTIVE DIESEL PARTICULATE FILTER (VERIFIED)[142]

Active filters are used when the engine exhaust temperature is too low for a passive DPF and for older and dirtier engines. Because these systems do not rely on exhaust gas temperatures for regeneration, but rather on heat addition to the exhaust gas stream by use of burners or other means, an active DPF can successfully operate at low exhaust gas temperature. To increase the exhaust temperature for efficient regeneration, some commercial filter systems have incorporated burners, electrical heaters or fuel injection into the exhaust stream. These burners or electric heaters use about 1% of the total fuel consumption.[143]

Although emissions reductions are maximized with the use of ULSD, an active DPF typically does not require the use of ULSD fuel.[144] Like passive DPFs, an active DPF can be used alone or in conjunction with a DOC to reduce gaseous hydrocarbons and carbon monoxide. The California Air Resources Board has verified Lubrizol's actively regenerated DPF, the Combifilter™, for off-road applications in 1996–2004 diesel engines. The Combifilter system is verified for an 85% reduction in PM emissions.[145]

FLOW-THROUGH FILTERS (VERIFIED)[146]

There are three types of flow-through filters: 1) the catalyzed wire mesh filter; 2) the pertubated path metal foil filter; and 3) the catalytic particulate oxidizer. Flow-through filters can be comprised of wire mesh or pertubated path metal foils. Like other filter materials they can be used with active systems or be catalyzed and perform as a passive system.

CWMF EPA verified reduction numbers (when used with FBC)

NO_x	0–9%
PM	55–76%
HC	75–89%
CO	50–66%

First, the catalyzed wire mesh filter (CWMF) is a new technology that has been EPA-verified for onroad use in conjunction with a fuel-borne catalyst.[147] A CWMF requires an exhaust gas temperature of 225°C for at least 25% of the daily duty cycle, which is lower than a DPF typically requires.[148] Thus, if a certain application does not allow for a DPF due to low exhaust gas temperatures, a CWMF might work. A CWMF weighs about the same as a DPF. EPA has verified the following emissions reduction rates for Clean Diesel Technologies, Inc.'s CWMF when used with a fuel borne catalyst: 0–9% for NO_x, 55-76% for PM, 75–89% for HC and 50–66% for CO.[149]

Generally, CWMFs should be visually inspected once per year, and in the event that the back pressure monitor signals an unreversed back pressure buildup, the CWMF should be returned to an authorized dealer for thermal cleaning.[150] However, several CWMF units that have been in operation for over a year have been essentially maintenance free.[151] Currently, with limited quantities in production, the price range for a CWMF is $5,500 to $7,000.[152] As with all emerging technologies, prices could decline as demand for the technology grows.

Second, the pertubated path metal foil flow-through filter is an emerging technology of similar performance. It can also be catalyzed both for emissions control performance and regeneration characteristics.

Third, a Catalytic Particulate Oxidizer (CPO)[153] is a new technology developed for heavy and medium duty onroad and offroad diesel engines. The CPO has recently begun the CARB verification process but, as of February 16, 2005, has not been EPA or CARB verified.[154] The CPO has been certified[155] in Europe and is currently undergoing another verification process in Switzerland.[156] The technology does not trap or filter particulates but oxidizes them continuously. Oxidization is the process of adding oxygen to break down pollutants.[157] The chemical reaction between catalyst material and exhaust gases, according to the manufacturer's data, results in over 90% reduction of HCs, CO and PM. The CPO requires a minimum exhaust temperature of 190°C. According to the manufacturer's specifications, the CPO does not store ash, eliminating the need to open and clean the filter regularly. The CPO typically creates less backpressure than a DPF. CPOs costs range between $6,000–$8,000, depending on the size of the equipment.[158]

DIESEL OXIDATION CATALYSTS (VERIFIED)[159]

A diesel oxidation catalyst (DOC) is a type of catalyst (catalytic converter), which chemically converts HC, CO, soluble organic fraction (SOF) and polycyclic aromatic hydrocarbons (PAH) to water vapor and carbon dioxide. A DOC is a flow-through metal or ceramic substrate coated with a precious metal catalyst (e.g. platinum). The outside of the DOC is metal and looks similar to an exhaust muffler. DOCs are a "bolt on" application and they can be easily installed, typically as a direct muffler replacement. DOCs do not require engine modifications and generally are maintenance free. Although ULSD fuel is not required, PM emissions reductions are increased with the use of low sulfur or ultra-low sulfur diesel fuel. DOCs can be installed on old and new pieces of equipment; for example, some new Caterpillar equipment already comes with a DOC.

DOC in-use reduction numbers

NO_x	0%
PM	20–30%
HC	50–90%
CO	70–90%

A DOC is a proven and efficient technology that destroys large fractions of toxic emissions. Typically, DOCs reduce approximately 50–90% HC and 70-90% CO.[160] As to PM reduction, DOCs are effective for reducing the SOF component of the particulate matter.[161] The SOF portion of PM is composed of organic material from engine fuel and lube oil that forms on the surface of elemental carbon (black soot).[162] The SOF part of the particulate matter is often referred to as *wet PM*.[163] As a result, depending on the SOF concentrations in the particulate matter of diesel exhaust, DOCs reduce approximately 20–30% of PM.[164] SOF concentrations tend to decrease with newer engines.[165] If the reduction of black soot (solid fraction) is the goal, a DPF or a CWMF are more effective technologies than a DOC.

DOCs also cut down on aldehyde, smoke and odor.[166] However, DOCs do

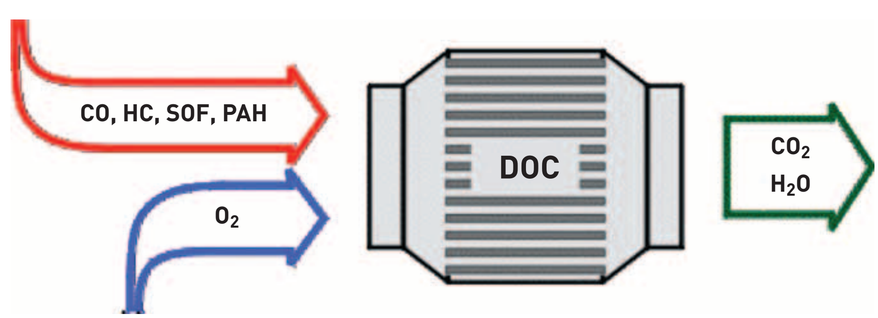
Construction equipment retrofit with a diesel oxidation catalyst.

COURTESY OF DONNA WEAVER, CONNECTICUT DEPARTMENT OF TRANSPORTATION

not remove NO_x. To increase emissions reductions, DOCs can be combined with other after-treatment technologies, including particulate filters. DOCs have already enjoyed widespread use in the onroad and nonroad sector. In fact, over 250,000 DOCs have been installed in new and retrofitted nonroad engines worldwide.[167] The cost of an oxidation catalyst is about 1–2% of the cost of new construction equipment. For example, the average cost for a DOC at the Boston Big Dig was about $2,500 per piece of construction equipment.[168] (See also the section on "Successes and Regional Programs.") Costs vary depending on the size of the equipment. Retrofit manufacturers will be able to give accurate cost estimates for each piece of equipment.

Overall, if a high number of construction vehicles should be retrofitted but funds are limited, DOCs might be an attractive option. DOCs might also be an attractive option if ULSD fuel is not available in the area. If ULSD fuel is not available, Environmental Defense encourages the use of low sulfur diesel (500 ppm) instead of typical nonroad diesel.

FIGURE 9
Schematic of a diesel oxidation catalyst



CRANKCASE EMISSIONS FILTRATION SYSTEMS WITH DOC (VERIFIED)

Crankcase emissions, on average, make up between 10–25% of total engine emissions over a prescribed test cycle but become very high (50–80%) on a relative basis when idling.[169] Targeting these emissions with pollution control technology can reduce overall engine exhaust pollution.

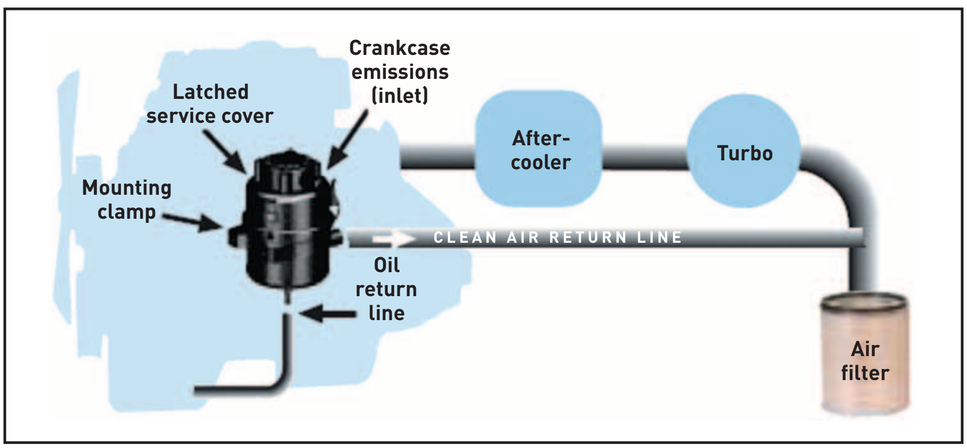
Crankcase filter with DOC in-use reduction numbers	
NO_x	0%
PM	25–33%
HC	12–34%
CO	42–52%

One example of a crankcase emissions filtration system is the Donaldson Spiracle™ crankcase filter. According to Donaldson, the filter eliminates 100% of all crankcase emissions and also eliminates under-hood fumes, reduces oil consumption by about 2–6 gallons/year and provides for a cleaner engine compartment. Donaldson reports that the Spiracle crankcase filter can be used alone, without other pollution control technologies, but EPA and CARB verification only apply the Spiracle when used with a DOC.

When combined with tailpipe pollution reduction technology, such as a DOC or a DPF, crankcase emissions filtration systems can achieve even greater emissions reductions. The Donaldson Spiracle crankcase filter is the only crankcase emissions reduction system that has been verified for use, when used with a DOC, by both EPA and CARB. The overall system reductions are based on the tailpipe reductions. Donaldson has approval for two different catalysts, depending upon the fuel sulfur level.[170] The use of a DOC with a Spiracle filter has been verified to reduce PM emissions by 25–33%, HC emissions by 12–34%, and CO emissions by 42–52%.[171] According to Donaldson, a DPF could be combined with the Spiracle filter in lieu of a DOC for a total engine emissions reduction of 89%. Neither EPA nor CARB have verified use of the Spiracle crankcase filter with a DPF.

The Spiracle system has a broad range of applications such as medium-duty and heavy-duty trucks, buses, off-road equipment and industrial generator sets.[172] For the retrofit market, the Spiracle system is available in two different sizes. For medium-duty applications, the end-user price for the system is approximately $325. For heavy-duty

FIGURE 10
Schematic of a crankcase emissions filtration system



Source: http://www.donaldson.com/en/engine/datalibrary/002509.pdf applications, the end-user price is approximately $435.[173]

Nitrogen oxides reduction

In general, the retrofits discussed above do not reduce NOx, a key precursor to ozone/smog. Thus, to achieve NO_x emissions reductions, additional strategies must be used. There are a number of ways to reduce NO_x pollution, but not all are retrofit devices. NO_x pollution control technology includes: Selective Catalytic Reduction (SCR), NO_x adsorbers, lean NO_x catalysts, exhaust gas recirculation and fuel emulsifiers. The California Air Resources Board has determined that NO_x removal is cost effective at a cost of up to $13,600 per ton of NO_x reduced.[174] The Texas Emissions Reduction Program follows a similar standard of $13,000 per ton of NO_x reduced.[175]

SELECTIVE CATALYTIC REDUCTION (IN DEVELOPMENT)[176]

SCR systems add a reductant[177] (usually ammonia or urea) to diesel exhaust to convert NO_x to N_2. The exhaust and reductant are processed by a catalyst to reduce PM, HC and NO_x. Initial results from SCRs being used in combination with other technologies, such as a DOC, show the following possible reduction rates: 60%–80% NO_x, 25% PM, 50–70% HC and CO.[178] SCR systems must maintain a careful balance of proper urea injection and exhaust temperature. Typically, a mobile SCR needs to reach an exhaust gas temperature of 200–250°C to work. As soon as the required exhaust gas temperature is reached, NO_x is being reduced. Thus, unlike a DPF, no minimal daily duty cycle is necessary for the SCR to function properly. However, if too much urea is injected, ammonia slip (ammonia being emitted through exhaust pipe) may occur. Also, low exhaust temperatures can actually increase NO_x formation.[179] To avoid ammonia slip, proper control of the correct amount of urea injection is needed. For that reason, some mobile SCRs have a NO_x sensor before and a NO_x sensor after the urea injector to remotely record data.[180]

SCR combined with DOC in-use reduction numbers

NO_x	60–80%
PM	25%
HC	50–90%
CO	70–90%

While aided by the use of ULSD fuel, SCRs can be used with low sulfur fuel (500 ppm).[181] SCR's high NO_x reduction potential makes them an attractive option for NO_x emissions reduction. SCRs can be combined with a DOC or a DPF. SCRs can be used in stationary (i.e. generator set, compressors and pumps) as well as mobile applications. Marine vessels, ferries and trains have successfully installed SCRs.[182] Mobile SCRs are currently being used in a number of construction pilot programs.[183] As of February 11, 2005, the only SCR system that EPA/CARB have verified is Extengine's ADEC system. Another verification of a mobile SCR system for onroad engines is expected by the end of 2005.[184]

Urea, the reductant that is typically used in SCR systems, is a substance that is contained in agricultural fertilizer. Thus, urea is plentiful in the United States and while supply should not cause a problem, lack of infrastructure sometimes does. If a fleet of several vehicles is being retrofitted with SCRs, a urea dispenser can be set up at the construction site. Infrastructure problems sometimes occur if only one or two vehicles are being retrofitted because of the small quantities of urea needed. Urea distribution costs range between $0.70 and $35 per gallon.[185] The amount of urea needed per engine is a function of engine-out NO_x levels, which differ depending on the year the engine was built, and vehicle size.[186] For every gallon of diesel fuel, about 5–10 ounces of urea are needed.[187]

The cost range for SCR systems varies greatly depending on the engine horsepower and the application. Mobile SCR systems in the 200–750 hp range cost between $12,500 and $15,000 for small quantities of SCR units.[188] These mobile SCR units are similar to an automotive type of system. Large stationary power generating SCR systems in the 750–2000 hp range can cost up to $80,000.[189]

NO_X ADSORBERS (IN DEVELOPMENT)

A NO_x adsorber, also sometimes referred to as a NO_x trap, works in two stages to remove NO_x from diesel exhaust. First, it uses a catalyst to adsorb NO_x emissions during lean operation.[190] Adsorb means to accumulate liquids or gases on a surface and "lean operation" occurs when the air-to-fuel ratio is high (perhaps 50 parts air to one part fuel), for example when a vehicle is going downhill or has a light load. Then, after the adsorber has been fully saturated with NOx, the system is regenerated (cleans itself) when the engine runs rich.[191] An engine runs "rich" when the air-to-fuel ratio is low (perhaps 29 parts air to one part fuel), for example when a vehicle is going uphill or has a heavy load. Also the exhaust gas temperature is very hot when an engine runs rich, which helps burn off the NO_x.

Unlike the other pollution controls discussed in this section, NO_x adsorbers are *not retrofittable,* i.e. they are not muffler replacements like diesel oxidation catalysts or diesel particulate filters and they can not be "added-on" like SCR. Instead they must be incorporated into the engine/vehicle design by the original equipment manufacturer. Although adsorbers have a high potential for NO_x emissions reductions, when sulfur-rich fuel is used the NO_x adsorption process is rapidly deactivated and rendered ineffective.[192] According to MECA, "To make this technology a commercial reality, low sulfur fuel is a requirement."[193] Near zero sulfur levels (less than 15 ppm sulfur) enable the application of catalyst and adsorption technology to run without interference.[194]

According to MECA, NO_x adsorber systems (in a low sulfur fuel environment) have the potential to provide "a high level of NO_x reduction across a wide range of operation conditions (temperature and NO_x concentration)—conditions which are consistent with the diversity in engine-out exhaust associated with both light- and heavy-duty diesel applications."[195] In fact, one manufacturer, Catalytica Energy Systems, states: "while still in early-stage development, our after-treatment approach is designed to offer a continuous production of a reactive reductant across a broad operating range to enable up to a 50% reduction in NO_x."[196] The operating temperature windows for NO_x adsorber technology ranges from 200 to 550°C.[197] At the present time, only prototypes of NO_x adsorbtion systems are available, so this technology is not yet commercially available or ready for CARB and/or EPA verification.

LEAN NO_X CATALYSTS (IN DEVELOPMENT)[198]

Lean NO_x catalyst technology can achieve a 10-40% reduction in NO_x emissions.[199]

Lean NOx catalyst in-use reduction numbers	
NO_x	10–40%

This technology is more effective when a supplemental hydrocarbon reductant is injected into the exhaust stream.[200] The hydrocarbons facilitate the conversion of NO_x to nitrogen and water vapor in the catalyst.[201] Lean NO_x catalysts are attractive because the technology requires no core engine modifications or additional infrastructure and can be used to retrofit older machines.[202]

Like NO_x adsorbtion technology, lean NO_x catalysts require low sulfur fuel; however, this technology has a higher tolerance for sulfur, requiring fuel with a sulfur content of less than 250 ppm versus the less than 15 ppm required for adsorbtion technology.[203] Additionally, this technology imposes a fuel efficiency penalty of 4–7%.[204]

Combinations of different retrofit devices

Retrofit devices as well as fuel additives can be combined to maximize emissions reductions. Some retrofit devices combine, PM, HC, CO with NO_x reduction in one unit.[205] Three examples follow:

SCR SYSTEM COMBINED WITH PM EMISSIONS CONTROL (VERIFIED)[206]

Extengine's ADEC system combines NO_x and PM control technology in one unit. The NO_x is reduced with an SCR system, and the PM control is achieved with a DOC.[207] This technology has been verified by CARB as achieving a 25% reduction in particulate matter emissions, and an 80% reduction in NO_x emissions.[208] The City of Houston has successfully retrofitted two excavators with the ADEC system and has praised the emissions benefits.[209] The ADEC system can also be incorporated with other DPFs for even higher PM reductions, although each individual retrofit application would require evaluation.[210] With a DOC, and SCR with Ammonia Slip Catalyst,[211] the cost of the ADEC System is $14,500 before installation.[212]

ADEC (SCR/DOC system) verified reduction numbers

NO_x	80%
PM	25%

Johnson Matthey is developing a technology that combines NO_x and PM control technology in one unit, the SCRT™ system (not verified as of February 2005) in which NO_x is reduced with an SCR and PM is reduced with a DPF. The SCRT system virtually eliminates HC and CO emissions and reduces PM and NO_x by 75–90%.[213] To date, approximately 100 SCRTs have been installed on heavy-duty diesel engines for field testing.[214] Johnson Matthey estimates that the SCRT will be commercially available by mid-2005.

Johnson Matthey (SCRT) field-testing reduction numbers (not verified as of February 2005)

NO_x	75–90%
PM	75–90%
HC	Over 90%
CO	Over 90%

LEAN NO_X CATALYST WITH PM EMISSIONS CONTROL (VERIFIED)[215]

Cleaire Advanced Emission Control's Longview™ diesel emissions control system is a CARB and EPA onroad verified NO_x reducing technology.[216] The Longview system reduces smoke, odors and NO_x by 25%, PM by 85%, and HC and CO by 90%.[217] The Longview system integrates a NO_x reducing catalyst (Lean NO_x Catalyst) and a catalyzed DPF. The Longview is a muffler replacement system. The use of ULSD fuel and an exhaust gas temperature of 260°C for at least 25% of the daily duty cycle are required.[218]

Cleaire's Longview Filter CARB verified reduction numbers

NO_x	25%
PM	85%
HC	90%
CO	90%

Longview systems have been successfully installed in onroad applications including refuse, transit, school bus, vocational work trucks, delivery trucks and line haul trucks. They have also been installed on nonroad mobile equipment such as motor graders, bucket loaders, agricultural tractors, agricultural water pumps and generators, some dating back to 1988.[219] The Longview needs regular maintenance; the maintenance interval depends on the number of hours of operation. Cleaire has developed maintenance procedures and equipment that are available through local Cleaire distributors. Pre-installation data logging is typically not required.[220] The cost range[221] is between $18,500-$20,500 (including installation and tax) for 6–11 liter engines and about $21,000 (including installation and tax) for 12–15 liter engines.[222]

Cleaire's Lonestar system achieves about a 25–30% NO_x, a 50–70% PM, and a 40–60% HC and CO emissions reduction.[223] The Lonestar is a combination of a Lean NO_x catalyst and a high-performance DOC.[224] The Lonestar is currently undergoing CARB's verification process[225] and Cleaire is expecting verification by the end of 2005.[226] The Lonestar costs about $12,500 (including tax and installation) for 6–12 liter engines and about $15,000 (including tax and installation) for 12–15 liter engines.[227]

Cleaire's Lonestar system in-use reduction numbers (not verified as of February 2005)

NO_x	25–30%
PM	50–70%
HC	40–60%
CO	40–60%

LOW PRESSURE EXHAUST GAS RECIRCULATION (IN DEVELOPMENT)[228]

Retrofitting exhaust gas recirculation (EGR) on a diesel engine offers an effective means of reducing NO_x emissions from the engine. Both low-pressure and high-pressure EGR systems exist, but low-pressure EGR is most suitable for retrofit applications because it does not require engine modifications.

As the name implies, EGR involves recirculating a portion of the engine's exhaust back to the charger inlet or intake manifold, in the case of naturally aspirated engines. In most systems, an intercooler lowers the temperature of the recirculated gases. The cooled recirculated gases, which have a higher heat capacity than air and contain less oxygen than air, lower combustion temperature in the engine and reduce NO_x formation. Diesel particulate filters are an integral part of any low-pressure EGR system, ensuring that large amounts of particulate matter are not recirculated to the engine.[229]

EGR systems are capable of achieving NO_x reductions of more than 40%. More than 1,500 EGR systems have been installed worldwide. EGR retrofit systems are now being installed in the U.S. on solid waste collection vehicles, buses and some city-owned vehicles. The cost of retrofitting EGR with a DPF on a typical bus or truck engine is about $13,000–15,000.

Currently, there is one low-pressure EGR system available commercially: STT Emtec's DNOx® system. SST Emtec is currently pursuing CARB onroad verification for this technology, and intends to pursue nonroad verification in the future.[230] STT Emtec has stated that though this technology has "not yet been used with nonroad engines, it can be," and the technology is commercially available for nonroad applications.[231]

Further details of the costs involved in replacing, refueling, and retrofitting diesel vehicles are available from EPA and MECA at http://www.epa.gov/otaq/retrofit/documents/meca1.pdf.

CHAPTER 7

Funding

Using cleaner diesel fuels or pollution control technologies on diesel engines powering construction equipment provides substantial public health benefits and improvements in air quality, but may also require investments in these fuels or technologies. Fortunately, state and local governments, fleet operators and vehicle owners have a number of options for financing cleaner diesel programs. This section of the *Cleaner Diesel Handbook* describes some programs on which state and local governments could model their own funding programs, followed by a discussion of funding available through federal sources.

State and local retrofit financing program models

CARL MOYER MEMORIAL AIR QUALITY STANDARDS ATTAINMENT PROGRAM

Both the state government of California and local air quality management districts play a substantial role in funding California's Carl Moyer Memorial Air Quality Standards Attainment Program (described in detail in the Success Stories section of this handbook). More information on the Carl Moyer Program is available on the California Air Resources Board web site, at: http://www.arb.ca.gov/msprog/moyer/moyer.htm.

In 1998/1999, the years of the program's inception, the legislature and the governor appropriated $25 million in funding for engine projects. Local air quality districts matched every two dollars of state money with a dollar contribution. In the third year of the program, state funding rose to $45 million for engine projects, and the district match was reduced to an average of one dollar per every $3.68 received. "In-kind" contributions, such as administrative costs, comprised up to 15% of match funds.[232]

In 2002, California voters approved Proposition 40, the Clean Water, Clean Air, Safe Neighborhood Parks, and Coastal Protection Act, which included approximately $40 million for Carl Moyer implementation.[233] These funds sustained the program through its fifth and sixth years. Carl Moyer's seventh year funding, approved through the 2004/2005 budget, was approximately $30.5 million.[234] The 2004/2005 budget also authorized an adjustment to Smog Check fees, establishing a continuous source of funding ($61 million/year) for the program.[235]

Assembly Bill 923, approved by the governor in September of 2004, authorized two additional sources of funding for the Carl Moyer program. The first was an increase in funding from tire fees, $25 million in 2005/2006 and $16 million in subsequent years. This brought state funding of the program to a total of approximately $86 million in 2005/2006 and $77 million thereafter.[236] The second increased the allowed surcharge on district-levied motor vehicle registration fees from $4 to $6.[237] Revenue from this program is expected to provide up to $55 million in local funding for Carl Moyer implementation in 2004/2005 and ensuing years.[238] Of the allowed $6 charge, $2 is to be used specifically for the Carl Moyer Program, for the new purchase, retrofit, repower, or add-on of equipment for previously unregulated agricultural sources, for the new purchase of schoolbuses pursuant to the Lower-Emission School Bus Progam, or for accelerated vehicle retirement or repair programs. The remaining $4 will continue to be used to "implement reductions in emissions from vehicular pollution sources."[239] The district collecting the surcharge may use only 5% of the surcharge for administration of the program. Emissions reductions achieved through this program may not be used to offset emissions reductions obligations, nor are they tradable (i.e. available for sale/purchase) in a marketable pollution permit system. Rather, credits resulting from this funding must be "retired."[240]

NORTH CAROLINA'S MOBILE SOURCE EMISSIONS REDUCTION GRANT PROGRAM

The North Carolina Department of Natural Resources, through its Division of Air Quality, sponsors the Mobile Source Emissions Reduction Grant program in order to provide economic incentives for actual emissions reductions from on and off-road mobile sources. More information on the Mobile Source Emissions Reduction Grant Program is available on the NC Department of Natural Resources web site, at http://daq.state.nc.us/motor/ms_grants/

Funded by a 1/64-cent per gallon tax on gasoline sold in North Carolina, the program has awarded 78 grants totaling $5.74 million statewide since 1995. In 2004, $350,000 was awarded to area school districts to install diesel oxidation catalysts on school buses.[241]

THE TEXAS EMISSIONS REDUCTION PLAN (TERP)

The Texas Emissions Reduction Plan (TERP) combines incentive programs, research, and technology development aimed at improving air quality in Texas. The centerpiece of the program provides grants to eligible projects in nonattainment areas and other, TERP-designated, counties to offset the incremental cost associated with the activities to reduce emissions of NO_x from high-emitting mobile diesel sources.[242] More information on the TERP program is available in the Success Stories section of this handbook, and on the Texas Natural Resources Conservation Commission's web site, at: http://www.tnrcc.state.tx.us/oprd/sips/terp.html.

The Texas Commission on Environmental Quality (TCEQ) administers the TERP program. The Legislature established the TERP in 2001 through Senate Bill 5, and amended it through House Bill 1365 in 2003.[243] Total 2004 revenue was $141.7 million, $127.5 million of which was used for grant programs. The program was extended through 2010 by the Texas Legislature in the 79th regular session.[244]

For more specific information on funding sources, please refer to the "Texas Emissions Reductions Plan: Biennial Report to the Legislature": http://www.tceq.state.tx.us/assets/public/comm_exec/pubs/sfr/079_04.pdf

In addition, your State or local community may have funding available. Fleet owners should contact their local and state air quality and transportation agencies to learn more about available funding.

Federal grant funding

Construction companies, fleet operators or individuals operating construction equipment in states or local communities without funding programs such as those described above may find federal grant programs an option for assisting with the cost of retrofitting vehicles or purchasing clean fuels. EPA and the Diesel Technology Forum have compiled lists of funding sources that may be available in your area. Please visit, http://www.epa.gov/otaq/retrofit/retrofunding.htm and http://www.dieselforum.org/factsheet/programs.html for further details.

CHAPTER 8

Onroad and nonroad EPA/CARB verification

Both EPA and CARB operate onroad and nonroad retrofit technology verification programs. These verification programs test retrofit devices in order to assign PM and/or NO_x emissions reduction values to specific devices. Recently, EPA or CARB have verified new retrofit technologies for the nonroad sector.[245]

There is now a Memorandum of Agreement (MOA) between the Environmental Protection Agency and the California Air Resources Board for coordination and reciprocity in diesel retrofit device verification. This MOA is intended to expedite the verification and introduction of innovative emissions reduction technologies. Additionally, this MOA should reduce the effort needed for retrofit technology manufacturers to complete verification. In the near future, EPA and ARB will provide guidance on how this agreement will be implemented. Please see http://www.epa.gov/otaq/retrofit/documents/epa-arb_moa.pdf for additional detail.

The objective of the EPA Voluntary Diesel Retrofit Program Verification Process is to introduce verified technologies to the market in a cost-effective manner, while providing customers with confidence that verified technologies will provide emissions reductions as advertised.[246] This verification process will evaluate the emissions reduction performance of retrofit technologies, including their durability, and identify engine operating criteria and conditions that must exist for these technologies to achieve those reductions.[247] According to the CARB web site:

> ...the ARB has several programs relating to sale, use, or modification of emission control systems. The programs are specific to the type of device as well as the market for which it was designed. The CARB Verification Procedure provides a way to thoroughly evaluate the PM emission reduction capabilities and durability of a variety of diesel emission control strategies as part of a retrofit in-use program. It ensures that emission reductions achieved by a control strategy are both real and durable and that production units in the field are achieving emission reductions consistent with their verification. The verification procedure requires a minimum PM reduction of at least 25%. Although not a requirement at this time, if a diesel emission control strategy also reduces NO_x emissions by at least 15%, that reduction can also be verified. CARB has established a tiered verification plan which is illustrated in the table below...[248]

In-use testing

In addition to verifying pollution control technologies at certain levels of

TABLE 5

CARB verification classifications for diesel emissions control strategies

Pollutant	Reduction	Classification
PM	< 25%	Not verified
	> 25%	Level 1
	> 50%	Level 2
	> 85%, or ← 0.01 g/bhp-hr	Level 3

Source: http://www.arb.ca.gov/diesel/verdev/background.htm emissions reductions, it is also very important to have rigorous in-use testing procedures. In-use testing—the process of testing a technology during real world operating conditions—yields the most accurate picture of emissions from a piece of equipment. By using a portable emissions testing system, researchers can get a better understanding of what is happening to emissions throughout the lifecycle of a piece of equipment. This procedure will ensure that technologies are performing at intended levels for the duration of use for a piece of equipment. For more details on EPA in-use testing requirements for manufacturers, please visit: http://www.epa.gov/otaq/retrofit/retrotesting.htm. More information about CARB's verification procedure and in-use compliance requirements is available at: http://www.arb.ca.gov/regact/dieselrv/dieselrv.htm.

Monitoring

While EPA and CARB in-use testing programs are designed for manufacturers of retrofit technologies, Environmental Defense believes that monitoring at a retrofit site can be a valuable part of a retrofit program because it allows all involved to see the actual pollution-control benefits of various retrofit strategies. This type of information can be invaluable to citizens and policy makers advocating on behalf of retrofit programs. We strongly encourage inclusion of good in-use monitoring procedures for all retrofit programs.

CHAPTER 9
Retrofit programs in State Implementation Plans

One way a state may be able to achieve emissions reductions that can be factored into its State Implementation Plan (SIP) is by including a rigorous retrofit program. A State Implementation Plan is a federally enforceable plan that describes a state's strategy for achieving and maintaining the public health based National Ambient Air Quality Standards (NAAQS).[249]

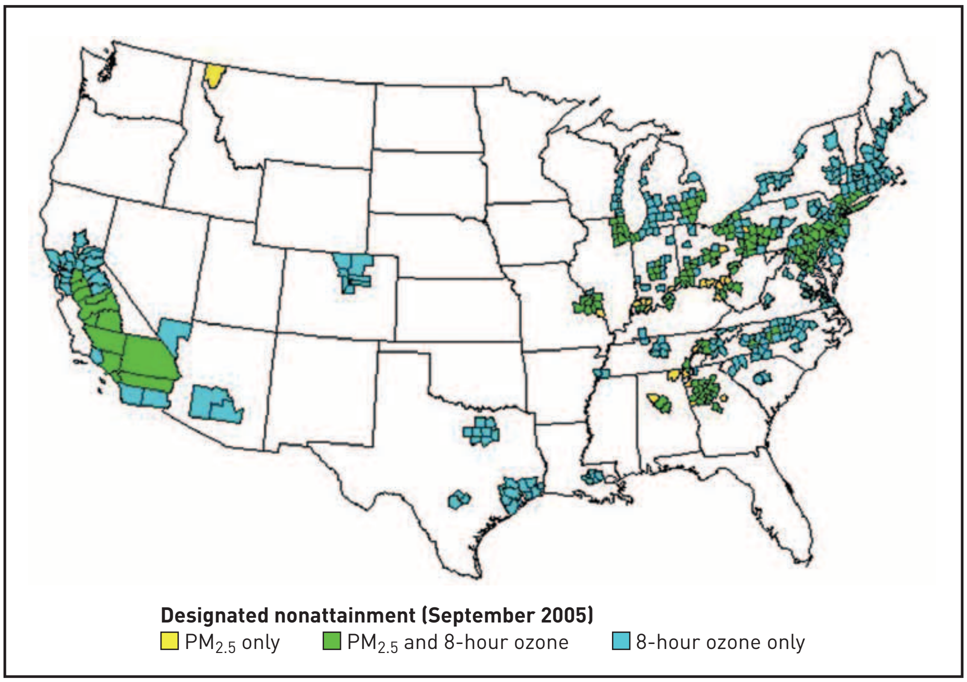
Recent EPA data shows that about half of all Americans live in places that fail to meet public health based standards for ozone and/or fine particulates. On April 15, 2004, EPA found 474 counties—home to 159 million Americans—out of compliance with the health-based eight-hour ozone standard.[250] In December 2004, EPA found that 224 counties in 20 different states are not meeting the nation's first $PM_{2.5}$ air quality standards.[251]

- To find out whether or not you live in a county that is meeting the public health based standards for ozone go to: http://www.epa.gov/ozonedesignations/statedesig.htm.
- To find out whether or not you live in a county that is meeting the federal $PM_{2.5}$ standards go to: http://www.epa.gov/pmdesignations/finaltable.htm.

Because more than half of the U.S. population lives in areas with unhealthy air, Environmental Defense believes that retrofit programs for all diesel equipment currently in use are critical components of any SIP.

If an area does want to quantify the benefits of a retrofit program, it may be able to do so by incorporating the benefits into the SIP, and it may also be able to use the benefits to demonstrate

FIGURE 11
Counties designated nonattainment for $PM_{2.5}$ and/or 8-hour ozone standard



Several counties have only a portion designated nonattainment. These counties are represented as whole counties on the map. Source: http://www.epa.gov/oar/oaqps/greenbk/mappm25o3.html conformity to its SIP. Areas with large retrofit programs should work with the appropriate EPA Regional Office[252] regarding SIP credits.[253] EPA encourages early consultation between project sponsors, planners, and EPA Regional Offices during the development of a SIP and the calculation of SIP credits. Including a program in a federally enforceable document should be done carefully as legal action can be taken if the program is not carried out as described.

Additionally, project sponsors should work with their state air quality and transportation agencies as well as federal DOT and EPA regarding inclusion of a retrofit program in a SIP or conformity determination and the credits of that program. The state air pollution agency should assume primary responsibility for the calculation of retrofit credits and incorporation into the SIP. With the guidance of the appropriate EPA Regional Office, the state should work with areas, sponsors, planners, fleets, etc. in implementing retrofit projects and programs for this purpose.

To learn more about calculating SIP credits from retrofit projects, please refer to the EPA web page at: http://www.epa.gov/otaq/retrofit/aqsipcalc.htm ("Guidelines For States On Establishing SIP Credits From Heavy-Duty Engine Retrofit Projects"). A NESCAUM report, prepared for EPA in 1999, is a good resource for more information on how these types of calculations are made.[254] EPA is expected to issue additional guidance on how to calculate SIP credits for retrofits in Spring of 2005.[255]

CHAPTER 10
Tools for spurring retrofits

In this section of the handbook, Environmental Defense offers a framework for implementing retrofits and best management practices to help protect public health and ensure clarity for the construction industry and others who wish to reduce the pollution from *existing* diesel construction equipment. Local and state governments seeking to employ clean diesel fuels and technologies in construction projects have a number of options to encourage contractors to retrofit their existing diesel vehicles, use clean fuels or enact other best management practices, such as anti-idling measures. Environmental Defense believes these commitments to cleaner, healthier air can be incorporated in several different ways. The ideas outlined below could be used as: (1) an administrative or legislative commitment; (2) a contract specification, as a preference in the bidding process; (3) in an environmental impact statement, (4) in an executive order; or (5) in a Community Benefit Agreement.

To reduce diesel emissions from existing nonroad vehicles, Environmental Defense recommends both the installation of best available technology and the use of cleaner fuels, including diesel fuel that has 15 ppm of sulfur or less (ULSD). In Environmental Defense's view, "best available" technology is that which achieves maximum emissions reduction of fine particulate matter and NO_x for a given particular engine type and application. Because specific emissions control technologies require different engine performance characteristics (temperature, duty cycles, etc.), each application has to be reviewed to determine the appropriate retrofit technology. Some flexibility and combinations of different technologies will be needed to achieve maximum emissions reductions for each application. Therefore, we suggest a cascading series of emissions-control choices, ranked according to emissions-reduction performance. In this way, states, local agencies, fleet operators and contractors will be able to match best technologies to the specific engine and application, and will be required to achieve the maximum possible clean air benefit.

To begin, there should be an overarching, central commitment to using DPFs in combination with a NO_x control. DPFs can achieve particle reductions of up to 90%. If no NO_x control is available, then the DPF can be used alone. If it is not possible to use a DPF, then Environmental Defense suggests using a DOC or a CWMF in combination with NO_x control. Diesel oxidation catalysts can achieve particle reductions of 20–30%, and CWMFs can reduce PM by more than 50%. If no NO_x control is available, then the DOC or CWMF can be used alone. Lastly, if no pollution control technology can be used, then Environmental Defense suggests using the cleanest possible fuels. Switching from onroad diesel fuel (500 ppm sulfur content) or from nonroad diesel fuel (about 2000-3000 ppm sulfur content) to ULSD (15 ppm sulfur content or less) can reduce particulate matter, smoke and sulfate emissions.[256]

Environmental Defense advises using only technologies that are on or in the queue for EPA's or CARB's verified lists to ensure that you are installing a high quality product on your diesel engine. However, states and local governments should include pilot or demonstration products if they wish to investigate promising new emissions control technologies.

DPF plus NO_x control

▼

If not technologically feasible

▼

DPF without NO_x control

▼

If not technologically feasible

CWMF or DOC plus NO_x control

▼

If not technologically feasible

CWMF or DOC without NO_x control

▼

If not technologically feasible

Cleaner fuels

Sample legislation regarding green contracting (retrofits and clean fuels)

According to the federal Clean Air Act, only EPA may set emissions standards for new nonroad engines and vehicles. EPA sets emissions standards for *new* nonroad engines and *new* nonroad vehicles. In May of 2004, EPA issued a rule setting emissions standards for new nonroad engines as well as regulating the amount of sulfur allowed in diesel fuel for the nonroad sector.[257] For more information on this new nonroad rule, please refer to: http://www.epa.gov/nonroad-diesel/. EPA has addressed new nonroad vehicles, but there are many older vehicles on the road today. Therefore, Environmental Defense recommends that states and local municipalities encourage retrofits and the use of cleaner fuels for *existing* nonroad vehicles. Cleaning up older diesel engines will be an important piece for reducing air pollution while the new nonroad rule phases in.

To encourage retrofits on existing nonroad equipment and the use of cleaner fuels, Environmental Defense suggests that state and local municipalities pass regulations (also sometimes referred to as "green contracting laws") regarding the use of retrofit technology on state/local municipality owned nonroad diesel vehicles as well as nonroad diesel vehicles used when contracting with state/local municipalities. Environmental Defense also suggests including the use of ULSD fuel (15 parts per million of sulfur or less) as one of the contract specifications.

NEW YORK CITY'S LOCAL LAW 77

New York City's Local Law 77 requires the City to use ULSD fuel and retrofits on city-owned nonroad equipment.[258] Local Law 77 also includes use of retrofits and ULSD as a contract specification in public works contracts.

Excerpts from New York City's Local Law 77, Section 1:[259]

b. (1) Any diesel-powered nonroad vehicle that is owned by, operated by or on behalf of, or leased by a city agency shall be powered by ultra low sulfur diesel fuel.

(2) Any diesel-powered nonroad vehicle that is owned by, operated by or on behalf of, or leased by a city agency shall utilize the best available technology for reducing the emission of pollutants.

c. (1) Any solicitation for a public works contract and any contract entered into as result of such solicitation shall include a specification that all contractors in the performance of such contract shall use ultra low sulfur diesel fuel in diesel-powered nonroad vehicles and all contractors in the performance of such contract shall comply with such specification.

(2) Any solicitation for a public works contract and any contract entered into as

a result of such solicitation shall include a specification that all contractors in the performance of such contract shall utilize the best available technology for reducing the emission of pollutants for diesel-powered nonroad vehicles and all contractors in the performance of such contract shall comply with such specification.

NEW YORK STATE ASSEMBLY LAW ON CONSTRUCTION IN LOWER MANHATTAN

The Coordinated Construction Act for Lower Manhattan, passed by both the New York State Senate and Assembly, commits New York State construction projects in lower Manhattan to control emissions by requiring that nonroad vehicles be powered with ULSD and retrofit with technologies such as oxidation catalysts, particulate filters or an emissions control technology that achieves the lowest particulate matter emissions.[260]

Excerpts from Section 4 of the Coordinated Construction Act for Lower Manhattan:

e. Notwithstanding any general, special or local law or rule or regulation to the contrary, a public agency shall require contractors and subcontractors to *use only ultra-low sulfur diesel fuel* to power the diesel-powered non-road vehicles with engine horsepower (HP) rating of 60 HP and above used on lower Manhattan redevelopment projects and, where practicable, to reduce the emission of pollutants by retrofitting such non-road vehicles with oxidation catalysts, particulate filters, or technology with comparable or better effectiveness. (emphasis added)

SACRAMENTO'S OZONE SUMMIT MODEL "GREEN CONTRACTING" ORDINANCE

The Sacramento Ozone Summit, a gathering of agency heads and elected officials from around the Sacramento federally designated Ozone Non-attainment Area, led to the design of a green contracting model ordinance by the Sacramento Metropolitan Air Quality Management District's Mobile Source Division. This ordinance offers a voluntary and flexible approach to reducing construction site emissions that would certify rental firms/construction firms as "green contractors." Being "green" would entail curtailing activities on "spare the air" days, mitigating emissions using ULSD or emulsified fuel, and replacing/retrofitting engines using Carl Moyer incentive funds or Sacramento Emergency Clean Air Transportation Funds (SECATF), which at one point totaled $28 million. "Green contractors" would then receive bidding bonuses that would give them a competitive advantage in the contract bidding process. "Green contractors" would also be subject to detailed monitoring of construction equipment.[261]

Excerpts from Section 3. of the Model "Green Contracting" Ordinance:

Within 90 days of adoption of this Chapter, the *(insert name of local agency)* shall designate a Program Manager *(such as the agency's manager responsible for procurement)* and shall develop and implement a Green Contracting Program. The Green Contracting Program must include a description of the plan to encourage contractors operating within the (*insert name of local agency*) to procure and to operate low-emission vehicles and to obtain low-emission fleet status for off-road equipment fleets and heavy-duty on-road vehicle fleets. The (insert name of local agency)'s Green Contracting Program must focus on fleet owners that have contracts for (insert name of local agency) business.

The (insert name of local agency) must include contract bid language that would implement the following Green Contracting Program requirements. See (c) for the exception to this requirement.

Sample contract specifications

BOSTON BIG DIG

Excerpt from Section 721.562 of the Big Dig Contract Specifications.

Methods that shall be used by the Contractor to control nuisance odors associated with diesel emissions from construction equipment include:

Turning off diesel combustion engines on construction equipment not in active use and on dump trucks that are idling while waiting to load or unload material for 5 minutes or more.

Establishing a staging zone for trucks that are waiting to load or unload material at the contract area, in a location where the diesel emissions from the trucks will not be noticeable to the public.

Locating combustion engines away from sensitive receptors such as fresh air intakes, air conditioners, and windows. *In addition to the above diesel emission control measures, all off-road diesel powered equipment used for this contract shall contain oxidation catalyst emission control equipment on the exhaust system side of the equipment.* (emphasis added)

Please note that when the Boston Big Dig contract specifications were drafted, ULSD fuel (sulfur content of 15 ppm) was not available in the Boston region. For that reason, DPFs could not be used as retrofit technology and DOCs only were used.

CONNECTICUT I-95 NEW HAVEN HARBOR CROSSING CORRIDOR IMPROVEMENT PROGRAM (NHCC PROJECT)

Connecticut's Department of Transportation (ConnDOT), the Connecticut Department of Environmental Protection, the Connecticut Department of Motor Vehicles, and the Connecticut Construction Industry Association worked together to create a contract specification to improve quality of life during the long-lasting I-95 New Haven Harbor Crossing Corridor Improvement Program.

Notice To Contractors (NTC)—Diesel Vehicle Emission Controls

All diesel powered construction equipment with engine horsepower (HP) ratings of 60 HP and above, that are on the project or are assigned to the contract for a period in excess of 30 days ***shall be retrofitted with Emission Control Devices and/or use Clean Fuels*** in order to reduce diesel emissions. In addition, all motor vehicles and/or construction equipment shall comply withal pertinent State and Federal regulations relative to exhaust emission controls and safety. (emphasis added)

Truck staging zones

The contractor shall establish truck-staging zones that are waiting to load or unload material at the contract area. Such zones shall be located where the diesel emissions from the trucks will have minimum impact on abutters and the general public.

Idling

Idling of delivery and/or dump trucks, or other diesel powered equipment shall not be permitted during periods of non-active use, and it should be limited to three minutes in accordance with the Regulations of Connecticut State Agencies Section 22a-174-18(a)(5).[262]

Environmental performance commitments in environmental impact statements

An Environmental Impact Statement (EIS) is a document required for major federal actions (or regional, state, or local actions funded with substantial federal monies) that may significantly affect the environment. Describing the positive and negative effects of the major project and citing alternative actions, an EIS serves as a tool for decision-making.

When a governmental agency plans a construction project, Environmental Defense strongly encourages the use of the cleanest possible fuel and pollution control technology in the Environmental Performance Commitments (EPC) section of the project's Environmental Impact Statement (EIS). This puts interested parties on notice that there will probably be future contract specifications that follow the guidelines established in the EIS. Thus, requirements for clean diesel equipment and clean diesel fuel can come out of the EIS and bidding process. Although the following two examples include the type of language that a government seeking cleaner diesel fuel and technology use might include in an Environmental Impact Statement's EPC section, Environmental Defense also recommends that:

- Emissions-reductions steps such as the use of ULSD or best available reductions technologies (BART) should be extended to onroad trucks servicing the construction site and all stationary diesel generators used in connection with construction.
- Emissions standards should cover nonroad vehicles of 50 HP and greater.
- Anti-idling measures include a powerful enforcement plan and mechanism.
- Regular emissions testing be conducted at construction sites, and that the results of these tests be made publicly available, to ensure compliance and accountability.
- Trucks and construction equipment be marked with a label or sticker that certifies that they are using ULSD fuel as well as retrofit technology.
- Truck staging zones should be established for diesel-powered vehicles waiting to load or unload materials. The zones should be located where diesel emissions will have the least impact on abutters and the general public.
- Idling should limited to three minutes for delivery and dump trucks and other diesel-powered equipment (with some exceptions).
- All work should be conducted to ensure that no harmful effects are caused to adjacent sensitive receptors, such as schools, hospitals, and elderly housing.
- Diesel-powered engines should be located away from fresh air intakes, air conditioners, and windows.

New York's Route 9A Draft Supplemental Environmental Impact Statement[263] can serve as a sample for how diesel emissions impacts can be mitigated and addressed in an EIS.

Excerpt from New York's Route 9A Draft Supplemental EIS, page 10:

All diesel construction engines—excluding trucks—would use ultra low-sulfur diesel (ULSD) fuel; where practicable, engines larger that 60 horsepower (HP) would include emissions reduction measures to reduce emissions of PM and volatile organic compounds (VOCs). For the purpose of this study, it was assumed that PM emissions from all such engines would be reduced by 40 percent—the average reduction achieved by using diesel oxidation catalysts (DOC). PM emissions may be further reduced in cases where diesel particle filters (DPF) would be used—85 percent reductions or higher can be achieved with this technology. Since it is uncertain at this time what emission reduction technologies would be most efficient with each equipment type, and since DOCs reduce more VOCs, which are ozone precursors and are of regional concern, the environmental performance commitments (EPCs) provide the flexibility to utilize either DOC or DPF control technologies. Therefore, the minimum PM emissions reduction of DOCs was assumed for the local impact analyses.[264]

Similarly, the Fulton Street Transit Center Draft EIS[265] also contains language suggesting the use of ULSD fuel and retrofit technology to mitigate the impact of unhealthy diesel emissions.

Excerpts from the Fulton Street Transit Center Draft EIS, page 2:

The Build Alternatives would be implemented with incorporation of Environmental Performance Commitments (EPCs). The EPCs consist of onsite measures that would include the use of ultra-low sulfur diesel (ULSD), with sulfur content less than 15–30 parts per million (ppm) fuel and retrofit technology in heavy-duty engines and off-road construction vehicles operating during the construction of the FSTC, including during year 2005/2006, the peak period of construction. Other EPCs include a dust control plan for the construction site including a soil erosion sediment control plan which would be part of the Construction Environmental Protection Program (CEPP). The dust control plan could include: spraying of a (non-hazardous, biodegradable) suppressing agent on disturbed soil and other surfaces; containment of fugitive dust; and adjustment of work practices to reflect meteorological conditions as appropriate.[266]

Community Benefit Agreements

Community Benefit Agreements (CBAs) can also serve as a tool to improve air quality. CBAs are project-specific contracts between developers of a major project and community organizations. CBAs are safeguards to ensure that local community residents share in the benefits of major developments. They allow community groups to have a voice in shaping a project, press for community benefits that are tailored to their particular needs, and enforce developer's promises.

The CBA process begins with interested members of the community, who identify how a proposed development project can benefit residents and workers. Once a list of potential benefits is determined, community members meet with the developer and/or representatives of the city to negotiate a CBA. Each CBA is unique, reflecting the needs of a particular community.

The first full-fledged CBA came in 2001, when a large coalition of community groups negotiated a far-reaching agreement with the developer of the Staples Center for the Los Angeles Sports and Entertainment District. This was followed by four more CBAs on projects across Los Angeles. A dozen additional projects in Los Angeles have community benefits provisions incorporated into their respective development agreements.

Many communities across the country are now using the community benefits model. In San Jose, two projects have incorporated community benefits provisions into the development agreements, while groups in at least six cities—Denver, Seattle, Milwaukee, Miami, New York and New Haven—are actively pursuing community benefits.[267]

In 2004, community groups, environmental organizations, and labor unions joined together and reached a CBA with Los Angeles World Airports (LAWA), the government entity that operates LAX.

Excerpts from the LAX CBA regarding reducing harmful diesel emissions via cleaner fuels and retrofits:

F. Construction Equipment.
1. Best Available Emissions Control Devices Required. LAWA shall require that all diesel equipment used for construction related to the LAX Master Plan Program be outfitted with the *best available emission control devices primarily to reduce diesel emissions of PM, including fine PM, and secondarily, to reduce emissions of NO_x*. This requirement shall apply to diesel-powered off-road equipment (such as construction machinery), on-road equipment (such as trucks) and stationary diesel engines (such as generators). The emission control devices utilized for the equipment at the LAX Master Plan Program construction shall be: (i) verified or certified for use by CARB for on-road or off-road vehicles or engines; or (ii) verified for use by EPA for on-road or off-road vehicles or engines. Devices certified or verified for mobile engines may be effective for stationary engines and that technology from EPA/CARB on-road verification lists may be used in the off-road context. (emphasis added)

5. ULSD and Other Fuels.
a. ULSD and Other Fuel Requirements. All construction equipment used for construction related to the LAX Master Plan Program *shall use only Ultra-Low Sulfur Diesel fuel (15 ppm or lower), so long as there are adequate supplies of ULSD* in the Southern California area. If adequate supplies of ULSD are not available in the Southern California area, then other fuels may be used, provided that the other fuels do not result in an greater emissions of fine PM or nitrogen oxides than that which would be produced by use of ULSD at 15 ppm or lower. Cost of ULSD shall not be a consideration in determining "adequate supplies." (emphasis added)

For more information on the LAX CBA go to: http://www.environmentaldefense.org/documents/4174_LAX_CBA_Summary.pdf. For the exact language of the LAX CBA go to: http://www.environmentaldefense.org/documents/4201_LAX_CBA_full.pdf.

APPENDIX A
Acronyms

BART Best Available Retrofit Technology

CARB California Air Resources Board

CA/T Project Central Artery Tunnel Project (Big Dig, Boston)

CCIA Connecticut Construction Industries Association

CNG Compressed Natural Gas

CO Carbon monoxide

CIAQC Construction Industry Air Quality Coalition

CPO Catalytic Particulate Oxidizer

CCRT Catalyzed Continuous Regenerating Technology

CRT Continuous Regenerating Technology

CWMF Catalyzed Wire Mesh Filter

DMV Department of Motor Vehicles

DOC Diesel Oxidation Catalyst

DOT Department of Transportation

DPF Diesel Particulate Filter

DTF Diesel Technology Forum

EGR Exhaust Gas Recirculation

EIS Environmental Impact Statement

EPA United States Environmental Protection Agency

EPC Environmental Performance Commitments

FBC Fuel Borne Catalyst

HC Hydrocarbon

LNG Liquefied Natural Gas

LSD Low sulfur diesel fuel (500 ppm)

MECA Manufacturers of Emissions Control Association

MOA Memorandum of Agreement

MTA Massachusetts Turnpike Authority

NAAQS National Ambient Air Quality Standards

NESCAUM Northeast States for Coordinated Air Use Management

NO_x Nitrogen oxides

OEM Original Equipment Manufacturer

OTAQ Office of Transportation and Air Quality

PHA Port of Houston Authority

PM Particulate matter

$PM_{2.5}$ Particulate matter smaller than 2.5 microns

PM_{10} Particulate matter smaller than 10 microns

SCAQMD South Coast Air Quality Management District

SCR Selective Catalytic Reduction

SIP State Implementation Plan

SOF Soluble Organic Fraction

TCEQ Texas Commission on Environmental Quality

TERP Texas Emission Reduction Program

TNRCC Texas Natural Resource Conservation Commission

ULSD Ultra low sulfur diesel fuel (15 ppm)

VOC Volatile organic compound

DISCLAIMER: Environmental Defense does not endorse any particular retrofit technology, retrofit technology manufacturer, or any of the companies listed here. This is not a comprehensive list of retrofit manufacturers and is intended to serve only to illustrate that there is a wide variety of choices available. This list was last updated in April 2005.

APPENDIX B
Retrofit manufacturers contact information

Manufacturer	PM, HC, CO control	NO_x control	Contact information
Argillon LLC http://www.argillon.com	SCR	SCR	Mr. Gary D. Keefe Argillon 5895 Shiloh Rd. Suite 101 Alpharetta, GA 30005 678.341.7532 404.409.3492 (Mobile) 678.341.7509 (Fax) gary.keefe@argillon.com
Caterpillar, Inc. http://www.caterpillar.com EPA Verified Technology for Heavy Duty Highway Use http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm	DOC (CCM: Catalyzed Converter Muffler DPF	SCR	Mr. Steve Hurd Mos 10 PO Box 610 Mossville, IL 61552-0610 309.578.6088 309.578.7152 (Fax) hurd_stephen_s@cat.com
Cleaire Advanced Emission Controls, LLC http://www.cleaire.com Longview® CARB and EPA Verified Technology for Heavy Duty Highway Use	Longview® Lonestar™	Longview® Lonestar™	John Egan 14775 Wicks Blvd. San Leandro, CA 94577 510.347.6163 800.308.2111 510.347.6181 (Fax) john.egan@cleaire.com Tim Taylor Director of Strategic Market Development 916.296.7049 707.220.7260 (Fax) tim.taylor@cleaire.com
Clean Air Power, Inc. www.cleanairpower.com	Catalytic Particulate Oxidizer (CPO)	Mobile SCR DOX SCAT (reduces NO-)	Frits Tan 9837 Whithorn Drive Houston, TX 77095 832-731-7372 (mobile) 281-463-8883 281-463-8951 fax ftan@cleanairpower.com
Clean Diesel Technologies Inc. http://www.cdti.com EPA Verified Technology for Heavy Duty Highway Use[a]	SCR FBC Platinum Plus® Purifier System (fuel borne catalyst plus DOC) FBC Platinum Plus® Purifier System and Catalyzed Wire Mesh Filter (FBC/CWMF) System	SCR	Mr. Glen Reid 300 Atlantic Street, Ste 702 Stamford, CT 06901 203.327.7050 203.323.0461 greid@cdti.com

DISCLAIMER: Environmental Defense does not endorse any particular retrofit technology, retrofit technology manufacturer, or any of the companies listed here. This is not a comprehensive list of retrofit manufacturers and is intended to serve only to illustrate that there is a wide variety of choices available. This list was last updated in April 2005.

Manufacturer	PM, HC, CO control	NO_x control	Contact information
Combustion Components Associates Inc. http://www.combustioncomponents.com	Mobile SCR		Mr. T.J. Tarabulski 884 Main Street Monroe, CT 06468 203.268.3139 203.223.8246 (Mobile) 203.261.7697 (Fax) tarabulski@cca-inc.net
DCL International Inc. http://www.dcl-inc.com	DOC, DPF (active and passive)		Gerry Wilson P.O. Box 90 Concord Ontario, Canada L4K1B2 905.660.6450, ext. 292 gwilson@dcl-inc.com
Donaldson Company, Inc. http://www.donaldson.com EPA Verified Technology for Heavy Duty Highway Use[b]	DOC, DPF (also offers crankcase emissions filtration system)		Mr. Fred Schmidt 1400 West 94th Street Minneapolis, MN 55440 952.887.3835 952.887.3008 (Fax) fschmidt@mail.donaldson.com
Engelhard Corporation http://www.engelhard.com EPA Verified Technology for Heavy Duty Highway Use[c]	DOC, DPF		Mr. Barry Bambo 101 Wood Avenue Iselin, NJ 08830 732.205.7277 732.205.5687 (Fax) Barry.Bambo@engelhard.com
Engine Control Systems, a Division of Lubrizol http://www.lubrizol.com/enginecontrol EPA Verified Technology for Heavy Duty Highway Use[d]	DOC AZ Purimuffler™, DPF Purifilter™		Ms. Michelle Bellamy 165 Pony Drive Newmarket, Ontario L3Y 7V1 800-661-9963 or 905-853-5800 (customer service) 905-853-5801 (Fax) ecs@lubrizol.com
Environmental Solutions Worldwide, Inc. Catalyst Division http://www.cleanerfuture.com/products/ EPA and CARB verification pending	Metallic (high performance— 50% plus PM reduction) DOC[e]		Mr. Frank Haas 571 Chrislea Rd. #5 Woodbridge, Ontario, Canada L4L8A2 905.850.9970 905.850.9925 Fax fhaas@cleanerfuture.com

DISCLAIMER: Environmental Defense does not endorse any particular retrofit technology, retrofit technology manufacturer, or any of the companies listed here. This is not a comprehensive list of retrofit manufacturers and is intended to serve only to illustrate that there is a wide variety of choices available. This list was last updated in April 2005.

Manufacturer	PM, HC, CO control	NO_x control	Contact information
Extengine Transport Systems, LLC http://www.extengine.com/index.html	Mobile and Stationary SCR (ADEC System) DOC Hybrid DPF-C (Diesel Particulate Filter and Catalyst) DPF (passive and active)	Mobile and Stationary SCR (ADEC System)	Mr. Phillip Roberts 1370 S. Acacia Ave Fullerton, CA 92831 714.774.3569 714.774.4036 (Fax) roberts@extengine.com
Fleetguard Emission Solutions	DOC (50% pm reduction), DPF		Western U.S.: Rob Ferguson 2931 Elm Hill Pike Nashville, TN 37214 615.366.9855 812.377.7137 (Fax) rob.r.ferguson@fleetguard.com Eastern U.S.: Jennifer Kain 2931 Elm Hill Pike Nashville, TN 37214 812-377-3132 812-377-7137 (Fax) jennifer.kain@fleetguard.com
International Truck and Engine Corporation http://www.greendieseltechnology.com	DOC, DPX	Green Diesel Technology	Mr. Peter Reba International Truck and Engine Corporation 4201 Winfield Road Warrenville, IL 60555 630-753-6537 (Office) 630-753-6537 (FAX) peter.reba@nav-international.com

DISCLAIMER: Environmental Defense does not endorse any particular retrofit technology, retrofit technology manufacturer, or any of the companies listed here. This is not a comprehensive list of retrofit manufacturers and is intended to serve only to illustrate that there is a wide variety of choices available. This list was last updated in April 2005.

Manufacturer	PM, HC, CO control	NO_x control	Contact information
Johnson Matthey – Environmental Catalysts and Technologies http://www.jmcsd.com/html/crt.html http://www.matthey.com/divisions/catalytic.html EPA Verified Technology for Heavy Duty Highway Use[f]	DOC, DPF (CRT or CCRT) SCRT(tm) systems (SCR+DPF) EGRT(tm) systems (EGR+DPF).	SCR SCRT(tm) systems (SCR+DPF) EGRT(tm) systems (EGR+DPF).	Mr. Brett Alkins 380 Lapp Road Malvern, PA 19355 610.341.8356 484.354.8159 (Mobile) 610.971.3116 (Fax) alkinbd@jmusa.com or Mr. Jim Hale 380 Lapp Road Malvern, PA 19355 610.476.0161 (Mobile) 717.246.6049 (Home Office) 610.971.3116 (Fax) halejr@jmusa.com or Marty Lassen 434 Devon Park Drive Wayne, PA 19087 610.341.3404 610.971.3116 (F) 610.476.0131 (M) lassen@jmusa.com
Nett Technologies, Inc. http://www.nett.ca	DOC: D-Series (low temperature DOC) M-Series (high performance, very low back pressure) NETT Series (standard DOC) DPF: SF Catalyzed SK Catalyzed (lower temperatures) SE Catalyzed (sulfur tolerant) SJ Catalyzed (lower temperature, sulfur tolerant)		For technical information: Mr. Wayne Borean 6707 Goreway Drive Mississauga, Ontario 800.361.6388 905.672.5949 (Fax) sales@nett.ca or Ms. Laura McBurney or Mr. Jorge Santos 800.631.6388
PuriNOx	PuriNOx	PuriNOx	Ron O. Dunfee 29400 Lakeland Blvd. Wickliffe, Ohio 44092 Office: (440) 347-6116 Fax: (440) 347-6978 Cell: (440) 463-2038 Email: rod@lubrizol.com

DISCLAIMER: Environmental Defense does not endorse any particular retrofit technology, retrofit technology manufacturer, or any of the companies listed here. This is not a comprehensive list of retrofit manufacturers and is intended to serve only to illustrate that there is a wide variety of choices available. This list was last updated in April 2005.

Manufacturer	PM, HC, CO control	NO_x control	Contact information
RYPOS Inc. http://www.rypos.com/html/index .html	Regular or catalyzed DPF Active DPF (Rypos Trap™)		Mr. Frank DePetrillo 3 Industrial Park Road Medway, MA 02053 Phone: 508.533-9655 Fax: 508.533-9656 Sales: fd@rypos.com

Engine Manufacturer Contacts
http://www.epa.gov/otaq/retrofit/cont_engmfrs.htm

EPA Verified Retrofit Technologies
http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm

CARB Verified Retrofit Technologies
http://www.arb.ca.gov/diesel/verdev/verdev.htm

[a] EPA, "Verified Products." August 11, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Last accessed 03/01/05.
[b] Ibid.
[c] Ibid.
[d] Ibid.
[e] DOC specifically designed for use on small compression ignition engines. Examples of these are small generators and construction equipment such as mixers and concrete floats. Environmental Technology Verification (ETV) Canada Inc. "Current Program Graduates and Licenses." Online resource, available at: http://www.etvcanada.com/English/e_progGrad.htm Last accessed 03/01/05.
[f] EPA, "Verified Products." August 11, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Last accessed 03/01/05.

APPENDIX C

Distributors of ultra low sulfur diesel fuel, emulsified fuels, fuel additives, and synthetic engine oil

Please check with your local Ultra Low Sulfur Diesel (ULSD) fuel distributor whether your fleet needs ULSD fuel No. 1 or No. 2. For example, if a fleet has been using Low Sulfur Diesel (500 ppm) No. 1 then ULSD No. 1 is needed. If only ULSD No. 2 is available and Low Sulfur Diesel No. 1 has been previously used, the engine needs to be tuned accordingly.

1. ULSD Fuel Brokerage

Ultra Low Sulfur Diesel Fuel Brokerage
Ultraco LLC
Mr. Timothy J. Niles
101 Farren Ct, Suite 100
Cary, NC 27511-4559
866.857.3487 or 919.380.0778
http://ultraco.us

2. ULSD Distributors

Northeast

Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, Washington, D.C.

Mr. David Wright, ConocoPhillips
600 North Dairy Ashford (77079-1175)
P.O. Box 2197
Houston, TX 77252-2197
Phone 281.293.1544
Fax 281.293.6113
David.W.Wright@conocophillips.com
http://www.conocophillips.com/products/ultralowsulfur/index.htm

or

Mr. Steven J. Levy, Sprague
4 New King Street
White Plains, NY 10604
Phone 914.328.6770 Fax 914.701.2819
914.284.2188 (Pager)
slevy@radenergy.com
www.spragueenergy.com

or

Ms. Debbie McNeal, Sunoco
Ten Penn Center
1801 Market Street
Philadelphia, PA 19103
800.842.0339 Ext. 1
Phone 215.977.3000
Fax 215.246.8119
DLMCNEAL@sunocoinc.com
http://www.sunocoinc.com/

Midwest, West Coast

Oregon, Washington, California, Arizona (Phoenix area), all Midwest States, Chicago area, Detroit area, Toledo area, Cleveland and Columbus area.

Ms. Renee Marchese, BP America Inc.a
28100 Torch Parkway 4th Fl.
Warrenville, IL 60555
Phone: 630.836.5504
Fax 630.836.5500
marcher2@bp.com

Pacific Northwest

Washington State, California.
Mr. David Wright, ConocoPhillips
600 North Dairy Ashford (77079-1175)
P.O. Box 2197
Houston, TX 77252-2197
Phone 281.293.1544
Fax 281.293.6113
David.W.Wright@conocophillips.com
http://www.conocophillips.com/products/ultralowsulfur/index.htm

South and Southwest

Texas, Colorado, Oklahoma, (southern) California, New Mexico, Kansas, Louisiana, Georgia, and Florida.

Mr. Ray Hernandez
Valero Energy Corporation
One Valero Place
San Antonio, TX 78212
Phone 210.345.2757
Fax 210.345.5930
Raymond.Hernandez@valero.com
http://www.valero.com/About+Valero/

3. Distributors of emulsified fuel

For further information or to purchase emulsified fuel, contact your local fuel distributor.

Mr. Thomas M. Sopko
The Lubrizol Corporation
29400 Lakeland Boulevard
Wickliffe, OH 44092-2298
Phone 440.943.4200
Fax 440.943.5337
tms@lubrizol.com

To purchase PuriNOx™ in the California and Texas area you may also contact:

Mr. Bill Alford
J.A.M. Distributing[b]
711 W.Bay Area Blvd Suite 310
Webster, Texas 77598
800.228.3848
Phone 713.844.7788
Fax 713.844.7789
jam@jamdistributing.com

or

Ms. Debbie McNeal
Sunoco[c]
800.842.0339 Ext. 1
Phone 215.977.3000
Fax 215.246.8119

4. Fuel additives

Mr. Glen Reid
Clean Diesel Technologies, Inc.[d]
300 Atlantic Street, Ste 702
Stamford, CT 06901
Phone 203.327.7050
Fax 203.323.0461
greid@cdti.com

or

Mr. Jim Baumert
AMSOIL Inc.[e]
AMSOIL Building
Superior, WI 54880-1527
Phone 631.587.5896 Fax 715.392.5225
http://www.lubedealer.com/baumert

or

The Stricklin Companies[f]
1415 Stratford Crt.
Del Mar, CA 92014
Phone 858-794-5700 Fax 848-794-2666
stricklin@worldnet.att.net

[a] BP America Inc. offers the users of BP's ULSD fuel (ECD®) risk management solutions enabling construction companies to manage their annual budget while reducing emissions at the same time. Construction companies can set a fixed fuel price over a set time period avoiding the risk of increasing fuel prices. For more information go to: http://www.ecdiesel.com/business/contruction.asp and http://www.bpdirect.com/products/risk.html

[b] J.A.M. Distributing also provides assistance with the installation of filters (EMISSION CONTROL TECHNOLOGY) to help further reduce emissions.

[c] AquaMix(tm) is Sunoco's emulsified fuel which has been verified by the EPA as an emission reduction diesel fuel. AquaMix™ emulsified diesel fuel is blended with Lubrizol's PuriNOx™ additive technology. AquaMix™ has been verified to reduce diesel particulate matter typically by 50% and NO_x emissions by 20%.

[d] Clean Diesel Technologies, Inc. sells a fuel borne catalyst called Platinum Plus.

[e] Amsoil Diesel Fuel Additive. AMSOIL also sells synthetic motor oil for heavy duty diesel engines (SAE 15W-40 or SAE 5W-30). Please contact Mr. Baumert for more information.

[f] Stricklin sells fuel additive called Blue Marble™. Please contact Stricklin for more information.

DISCLAIMER: Environmental Defense does not endorse any particular product on this list. This is not intended to be comprehensive and is presented for informational purposes only. This list was last updated in April 2005.

APPENDIX D

Summary of retrofit technology status

Status	CARB or EPA verified for onroad use	CARB or EPA verified for nonroad use	In use in nonroad engines*	Known to be pursuing onroad verification	Known to be pursuing nonroad verification	In development
Retrofit technologies						
PM control						
Diesel Particulate Filter (DPF)	●		●	Verified		
Active DPF		●	●		Verified	
Flow-through filters (including CWMF)	●		●	Verified	●	●
Diesel Oxidation Catalyst (DOC)	●	●	●	Verified	Verified	
Closed Crankcase Filter System with DOC—Donaldson Spiracle with DOC Muffler	●	●	●	Verified	Verified	
NO_x control						
Selective Catalytic Reduction (SCR)			●		●	●
NO_x Adsorbers						●
Lean NO_x Catalysts	● (w/ DPF)		●	Verified		
PM and NO_x control						
Low Pressure Exhaust Gas Recirculation (EGR)				●		
SCR System with PM Emission Control		●	●		Verified	
Lean NO_x Catalyst with DPF—Cleaire Longview	●		●	Verified	●	
Lean NO_x Catalyst with DOC—Cleaire Lonestar			●	●		
Retrofit technologies and cleaner fuels						
Fuel Borne Catalyst (FBC) with DOC—Platinum Plus	●		●	Verified	●	
FBC with Catalyzed Wire Mesh Filter (CWMF)—Platinum Plus	●			Verified		
Emulsified Diesel Fuel with DOC		●	●		Verified	
Cleaner fuels and additives						
Emulsified Diesel Fuel—PuriNOx	●	●	●	Verified	Verified	
Biodiesel	●		●	Verified		

*In order for a technology to be considered "in use," it must: 1) be commercially available, and 2) have been used in at least 2 projects with varying locations.

APPENDIX E

Retrofit technology cost and emissions reductions summary

	Cost (excluding installation)	NO_x	PM	HC	CO
Retrofit technologies and emissions reductions					
PM control					
Diesel Particulate Filter (DPF)	$7,000–$12,000	0%	Up to 90%	Up to 90%	Up to 90%
Active DPF	$10,000–$30,000	0%	85%	0%	0%
Flow-through Filters (including CWMF)	$5,000–$7,000	0-9%	55–76%	75–89%	50–66%
Diesel Oxidation Catalyst (DOC)	$1,200–$2,500	0%	20–30%	50–90%	70–90%
Closed Crankcase Filter System with DOC—Donaldson Spiracle with DOC Muffler	$1,900	0%	25–33%	12–34%	42–52%
NO_x control					
Selective Catalytic Reduction (SCR)	Mobile: $12,500–$15,000 Stationary: up to $80,000	60–80%	25%	50–90%	70–90%
NO_x adsorbers	In development	90% or more	10–30%	90%	90%
Lean NO_x Catalysts	$6,500–$15,000+	10–40%	Up to 80%	0%	0%
PM and NO_x control					
Low Pressure Exhaust Gas Recirculation (EGR)	$13,000–$15,000	40% or more	90% or more	90% or more	90% or more
SCR System with PM Emission Control	$14,500	80%	25%	50–90%	50–90%
Lean NO_x Catalyst with DPF - Cleaire Longview 90%		$18,500–$21,000	25%	85%	90%
Lean NOx Catalyst with DOC—Cleaire Lonestar	$12,500	25–30%	50–70%	40–60%	40–60%
Retrofit technologies and cleaner fuels					
Fuel Borne Catalyst (FBC) with DOC—Platinum Plus	Cost of DOC. Fuel economy gains from use of Platinum Plus are expected to outweigh its incremental cost.	0–5%	25–50%	16–50%	25–50%
FBC with Catalyzed Wire Mesh Filter (CWMF)—Platinum Plus	Cost of CWMF. Fuel economy gains from use of Platinum Plus are expected to outweigh its incremental cost.	0–9%	55–76%	75–89%	50–66%
Emulsified Diesel Fuel with DOC	$0.25 per gallon + $1,500–$2,500	25%	95%	85%	75%
Cleaner fuels and additives					
Emulsified Diesel Fuel—PuriNOx	$0.25 per gallon	9–20%	16.8–58%	(35%)–33%	(20–120%)
Biodiesel (20)	$0.15 per gallon	(2%)	10%	21%	11%
Biodiesel (100)	$0.50 per gallon	(10%)	47%	67%	48%

Emissions reductions data derived from CARB or EPA verified reduction levels where possible.
(Parenthesis denote increase)

APPENDIX F

Examples of nonroad retrofit technology use

Status	In use in nonroad engines*	Two projects/sites in which the technology/fuel has been used
Retrofit technologies		
PM control		
Diesel Particulate Filter (DPF)	●	1. World Trade Center, NYC, NY—Caterpillar 966 Wheel loaders 2. American Asphalt, CA—Caterpillar 966GII Wheel loader
Active DPF	●	1. World Trade Center, NYC, NY—Rypos trap installed on a diesel 600 kW electrical generator 2. Riverside, CA—three Caterpillar backup generators (100, 225, and 350 kw) retrofit with Rypos trap
Flow-through Filters (including CWMF)	●	1. Nationwide . many non-metal mining applications on Deutz and Caterpillar engines, 100-275 hp 2. World Trade Center Site, NYC, NY—Two cranes retrofit with an ESW particulate reactor
Diesel Oxidation Catalyst (DOC)	●	1. World Trade Center, NYC, NY—Komatsu PC200 5.9 liter engine Excavator 2. Big Dig, Boston, MA—more than 200 pieces of equipment successfully retrofit
Closed Crankcase Filter System with DOC—Donaldson Spiracle with DOC Muffler	●	Between the Port of Los Angeles and the Port of Long Beach in CA, this system has been successfully installed on approximately 400 yard hustlers, top picks/side picks, and rubber tired gantry-cranes.
NO_x control		
Selective Catalytic Reduction (SCR)	●	1. Richmond, CA—Caterpillar modular SCR installed on a gas power module, model G3516B LE 2. Palm Desert, CA—Mobile SCRs installed on seven construction vehicles
NO_x Adsorbers		Not in commercial use for non-road engines
Lean NO_x Catalysts	●	See Lean NO_x Catalyst with DOC, below.
PM and NO_x control		
Low Pressure Exhaust Gas Recirculation (EGR)	●	Not in commercial use for non-road engines
SCR System with PM Emission Control	●	1. Houston, TX—Houston City has retrofit Cummins 6BTA 5.9L engines on 6 Gradall excavators 2. Port of Houston, TX—GR Birdwell has retrofit several pieces of construction equipment
Lean NO_x Catalyst with DPF—Cleaire Longview	●	1. Fresno, CA—Case IH STX 375 wheel lower and a Komatsu WA450 wheel loader 2. CADOT, California - John Deere672 CH motor grader
Lean NO_x Catalyst with DOC—Cleaire Lonestar	●	1. Concord, CA—Onan stationary 300 DGFC generator 2. Sacramento, CA—Caterpillar 8W2517 (16G) motor grader
Retrofit technologies and cleaner fuels		
Fuel Borne Catalyst (FBC) with DOC—Platinum Plus	●	1. Q-Bridge Project, CT—Starr construction excavator, Samsung 280LC 2. New York City, NY—Vergona crane, unknown model
FBC with Catalyzed Wire Mesh Filter (CWMF)—Platinum Plus		Not in commercial use for non-road engines

Status	In use in nonroad engines[a]	Two projects/sites in which the technology/fuel has been used
Emulsified Diesel Fuel with DOC	●	Between the Port of Los Angeles and the Port of Long Beach in CA, approximately 250 yard hustlers, top picks/side picks, and rubber tired gantry-cranes, etc have DOCs and use PuriNOx.
Cleaner fuels and additives		
Emulsified Diesel Fuel—PuriNOx	●	1. Port of Houston, TX—approximately 50+ pieces of cargo-handling equipment use PuriNOx 2. Extensive, multi-engine/model testing conducted by USEPA and by Air Improvement Resources
Biodiesel	●	1. Hutchinson Salt Co, KA—uses B100 in all underground diesel machinery, 32,000 gallons/year 2. Pioneer Hi-Bred Intl., Charlotte, NC—uses biodiesel on all farm and tractor equipment

*In order for a technology to be considered "in use," it must: 1) be commercially available, and 2) have been used in at least 2 projects with varying locations.

APPENDIX G
Sample action letter

Dear [Decision Maker].

I write to direct your attention to the growing health and environmental impacts associated with diesel engines, and to encourage you to address this problem. Diesel engines, the workhorses of America's economy, are a significant source of air pollution in many communities across the country. Fortunately, cost-effective technology exists to reduce harmful diesel emissions by as much as 90%. Your help is needed to ensure that this technology is taken advantage of.

Emissions from diesel engines contain almost 40 toxic substances and contribute to a laundry list of adverse health effects including: asthma, cardiovascular and respiratory problems, strokes, heart attacks, lung cancer and premature death. Of special concern are two main pollutants: fine particulate matter, which lodges deep in the lung, and oxides of nitrogen (NO_x), which are precursors to smog. Diesel engines are a significant source of fine particulates and NO_x, and recent EPA data shows that about half of all Americans live in places that fail to meet basic health standards for one or both of these pollutants.

Nonroad diesel engines are, quite literally, engines that power vehicles that do not normally operate on roads. They include, for example, locomotives, agricultural equipment (i.e., tractors), construction and mining equipment (i.e., graders and back hoes), and ships. Collectively, nonroad engines discharge more dangerous fine sooty particles than any other source in the transportation sector.

The EPA recently established rigorous emissions standards for new nonroad diesel engines. Unfortunately, the full pollution reduction and public health benefits of the non-road rule will not be realized for decades because they only apply to new non-road diesel engines and not to older, dirtier diesel engines, which have a long life span. A child born today may still be breathing soot from a backhoe in her neighborhood when she graduates from college—unless that backhoe is replaced with a newer, cleaner one, or is retrofit with emissions controls.

Public and private leadership is needed to ensure that dirty diesel engines in our community are replaced or retrofit to reduce their polluting potential. As a community leader, I am asking you to implement programs to reduce pollution from dangerous diesel engine exhaust from vehicles in use in our community. Environmental Defense's Cleaner Diesel Handbook, available at: www.environmentaldefense.org/go/dieselhandbook, is a good starting point. The handbook shows that there is a cost-effective way to reduce the adverse health effects of diesel pollution.

The Cleaner Diesel Handbook outlines some simple ways to reduce diesel pollution, like enforcing idling laws, using clean fuels (like ultra-low sulfur diesel), and best available retrofit technologies that can reduce diesel emissions by up to 90%. It also offers a variety of methods for implementing successful diesel retrofit programs. With your leadership, these tools can reduce air pollution from diesel engines and protect public health in our community. Thank you.

Sincerely,
[Your name]
[Your address]

Notes

[1] Environmental Defense is a national non-profit environmental organization, headquartered in New York City, with 400,000 members around the country and over 50,000 members and activists in New York. The Living Cities program at Environmental Defense is focused specifically on actions that will help to improve water and air quality, clean up contaminated lands, support sound transportation investments and will reduce greenhouse gases (GHGs). Environmental Defense is not affiliated with any manufacturer or supplier identified in this handbook, and Environmental Defense does not endorse any particular supplier, retrofit or fuel technology manufacturer. This handbook provides only a general overview of commercialized nonroad retrofit technology and cleaner fuel technology options. We provide information about specific companies or suppliers for informational purposes only, but inclusion in, or omission from, this handbook should not be interpreted as a judgment about a particular technology or company. Questions about specific products, applications, emerging technologies, or next steps should be taken up directly with appropriate private sector companies or consultants.

[2] EPA, "Clean Air Nonroad Diesel Rule Summary." June 8, 2004. Office of Transportation and Air Quality. Online resource, available at: http://www.epa.gov/otaq/regs/nonroad/equip-hd/2004fr/420f04029.htm Last accessed 03/01/05.

[3] EPA, "Press Release: New Clean Diesel Rule Major Step in a Decade of Progress." May 11, 2004. Online resource, available at: http://yosemite.epa.gov/opa/admpress.nsf/b1ab9f485b098972852562e7004dc686/f20d2478833ea3bd85256e91004d8f90?OpenDocument Last accessed 03/01/05.

[4] *Ibid.*

[5] EPA, "8-Hour Ground-level Ozone Designations." 08/13/04. Online resource, available at: www.epa.gov/ozonedesignations Last accessed 03/01/05.

[6] EPA, "Fine Particle (PM 2.5) Designations." Online resource, available at: http://www.epa.gov/pmdesignations/regions/region2desig.htm Last accessed 03/01/05.

[7] Calculated from 1999 EPA National Scale Assessment of Air Toxics data.

Environmental Defense, "Scorecard, 2002." Online resource, available at: http://www.scorecard.org/ Last accessed 03/01/05.

[8] *Ibid.*

[9] *Ibid.*

[10] EPA, "National Emission Inventory (NEI): Air Pollutant Emission Trends." Online resource, available at: http://www.epa.gov/ttn/chief/trends/index.html Last accessed 03/01/05.

[11] California Office of Environmental Health Hazard Assessment, Air Toxicology and Epidemiology Section, "Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant," *Health Risk Assessment for Diesel Exhaust* app. III, part B, as approved by the Scientific Review Panel, April 22, 1998. Online resource, available at: ftp://ftp.arb.ca.gov/carbis/regact/diesltac/partb.pdf Last accessed 03/01/05.

[12] Air Pollution and Birth Weight Among Term Infants in California, PEDIATRICS Vol. 115 No. 1, January 2005, pp. 121–128 Online resource, available at:
http://pediatrics.aappublications.org/cgi/content/abstract/115/1/121?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=&author1=Woodruff&fulltext=Birth+weight&andorexactfulltext=and&searchid=1105556093372_12826&stored_search=&FIRSTINDEX=0&sortspec=relevance&resourcetype=1&journalcode=pediatrics Last accessed 03/01/05.

[13] Krewski, D., Burnett, R.R., Goldberg, M.S., Hoover, K., Siemiatycki, J., Jerrett, M., Abrahamowicz, M., White, W.H., and Others. Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality. Health Effects Institute, July, 2000.

[14] R. Wilson and J. Spengler, eds., "Particles in Our Air: Concentrations and Health Effects," (1999): 212.

[15] U.S. Department of Health and Human Services, National Institutes of Health, National Heart, Lung and Blood Institute; Data Fact Sheet: Asthma Statistics; January 1999. See also http://www.environmentaldefense.org/documents/2655_MotorAirPollutionAsthma.pdf

[16] NY State Department of Health and Mental Hygiene, "Asthma Facts." Second Edition, May 2003. Page 7. Online resource, available at: http://nyc.gov/html/doh/pdf/asthma/facts.pdf Last accessed 03/01/05.

[17] Manufacturers of Emissions Controls Association, "Frequently Asked Questions About the Installation of Emission Controls on Existing Diesel Engines." Online resource, available at: http://www.meca.org/jahia/Jahia/engineName/filemanager/pid/224/retrofitFAQ%20%28revised%29.pdf?actionreq=actionFileDownload&fileItem=712 Last accessed 03/01/2005.

[18] Based on email correspondence with Roger Suter of Detroit Diesel, Inc. on August 4, 2004.

[19] EPA Tier 0 standards refer to unregulated diesel engines. Tier 1 standards refer to the nonroad diesel engine emissions control regulations adopted by EPA in 1994. The regulations came into effect for new nonroad diesel engines greater than 37 kilowatts (50 horsepower) between 1996 and 2000. Tier 2 standards refer to stricter regulations that were phased in between 1999 and 2000. Tier 3 standards applied to engines between 37 kilowatts and 560 kilowatts (50 and 750 hp), and will be phased in between 2006 and 2008. Source: EPA, "Reducing Air Pollution From Nonroad Engines." April 2003. Online resource, Last accessed 09/11/05. Available at: http://www.epa.gov/otaq/cleaner-nonroad/f03011.pdf

[20] (Using California's Carl Moyer Program assumptions for an unregulated engine's replacement with a Tier One engine, NO_x emissions would go from 11 grams per brake horsepower-hour (g/bph-hr) to 6.6 g/bph-hr and PM emissions would go from 0.53 g/bph-hr to 0.1 g/bph-hr. For a Tier Two replacement, NMHC + NO_x emissions would decrease to 4.2 g/bph-hr and PM would decrease to 0.1 g/bph-hr.) Based on email correspondence with Stephen Hurd of Caterpillar Inc. on August 30, 2004.

[21] This definition is narrower than the one found in the EPA's "Retrofit Glossary." The EPA glossary is an online resource, available at: http://www.epa.gov/otaq/retrofit/glossary.htm ast accessed 03/01/2005.

[22] EPA, "Voluntary Diesel Retrofit Program: Glossary" Office of Transportation and Air Quality. Online resource, available at http://www.epa.gov/otaq/retrofit/glossary.htm Last accessed 03/01/2005.

[23] Information provided by Alex Kasprak from the Boston Big Dig project and various retrofit manufacturers. The operator of the construction equipment to be retrofitted can typically install the replacement muffler containing the DOC.

[24] Information provided by Johnson Matthey.

[25] California Air Resource Board, *Diesel PM Control Technologies, Appendix IX*, October 2000.

[26] Reed Business Information. "Mid-Sized Loaders Pack Plenty of Power." August 24, 2004. *Construction Equipment.* Online resource, available at: http://www.constructionequipment.com/buyingfile/ce03ga002.asp Last accessed 03/01/2005.

[27] British Petroleum, "Low Sulpher Diesel—Frequently Asked Questions." 2003. Online resource, available at: http://www.bp.com.au/products/fuels/low_sulphur/faq.asp?menuid=ec Last accessed 03/01/2005.

[28] EPA, "Press Release: New Clean Diesel Rule Major Step in a Decade of Progress." May 11, 2004. Online resource, available at: http://yosemite.epa.gov/opa/admpress.nsf/b1ab9f485b098972852562e7004dc686/f20d2478833ea3bd85256e91004d8f90?OpenDocument Last accessed 03/01/2005.

[29] EPA, "Proposed Rules." *Federal Register.* Volume 68, Number 100. May 23, 2003. Online resource, available at: http://www.epa.gov/fedrgstr/EPA-AIR/2003/May/Day-23/a9737c.pdf Last accessed 03/01/2005.

[30] Joe Kubsch. "Retrofit Emission Control Technologies for Diesel Engine." MECA, November 4, 2003. Online resource, available at: http://www.4cleanair.org/JoeKubsh.pdf Last accessed 03/01/2005.

[31] EPA, "Idling." July 21, 2004. Online resource, available at: http://www.epa.gov/region1/eco/diesel/idling.html Last accessed 03/01/2005.

[32] *Ibid.*

[33] For more information on EPA regulations, please see http://www.epa.gov/otaq/url-fr/fr29jn04.pdf Last accessed 03/01/2005.

[34] For more information on the WTC 7 retrofits, please contact: NESCAUM at 617.259.2000.

[35] Environmental Solutions Worldwide, Inc., "Environmental Solutions Worldwide, Inc.

Puts Diesel Emission Controls to Work at World Trade Center Construction Site." June 1, 2004. Online resource, available at: http://www.cleanerfuture.com/june0104.htm Last accessed 03/23/05.

36 All information in this section is from a report conducted by M.J. Bradley and Associates, Inc. for the Port Authority of NY/NJ on August 9, 2004. This report is available online at: http://www.mjbradley.com/documents/PANYNJ_WTC_Final_Report-09Aug04.pdf

37 N.Y. ALS Chapter 259, Assembly Bill 11700. 2004.

38 New York State Governor's Office. "Press Release: Governor Signs Bill Creating the Coordinated Construction Act for Lower Manhattan." August 10, 2004. Online resource, available at: http://www.state.ny.us/governor/press/year04/aug10_1_04.htm Last accessed 03/02/05.

39 N.Y. ALS Chapter 259, Assembly Bill 11700. 2004.

40 Investigation of Diesel Emissions Control Technologies on Off-Road Construction Equipment at the World Trade Center and PATH Re-Development Site" Report prepared for the Port Authority of NY/NJ on August 9, 2004. Pages 39–40. This report is available online at: http://www.mjbradley.com/documents/PANYNJ_WTC_Final_Report-09Aug04.pdf.

41 New York City Council, "Local Laws of the City of New York for the Year 2003: No. 77. §2(d)(1)." December 22, 2003. Available online, at: http://www.nyccouncil.info/pdf_files/bills/law03077.pdf Last accessed 03/02/05.

42 *Ibid.*

43 New York City's rules Concerning the Use of ULSD and Emissions Control Technology in Nonroad Vehicles Used in City Construction are available online at www.nyc.gov/html/dep/pdf/batrule.pdf

44 Fulton Street Transit Center Draft Environmental Impact Statement, and Section 4(f) Evaluation, Chapter 12, page 31 (2004).

45 For more information, please contact: Alex Kasprak via email at akasprak@bigdig.com or via phone at 617-556-2462.

46 Massachusetts Turnpike Authority, "Big Dig: Project Schedule and Timeline." Online resource, available at: http://www.masspike.com/bigdig/updates/timeline.html Last accessed 03/04/05.

47 Such small, movable cranes that move on tracks for underground tunnel construction included "nichi lifts" and "mantis cranes." Although stationary cranes can be retrofitted with DOCs, it was decided that those cranes not be retrofitted for the Big Dig project. At the time when the decision to retrofit construction equipment with DOCs was made, it was not clear whether a DOC might affect the stationary crane's heavy lift. Phone conversation with Alex Kasprak, September 8, 2004.

48 EPA, "The Big Dig—Program Launch." Online resource, available at: http://www.epa.gov/otaq/retrofit/documents/bigdig_case_01.htm Last accessed 03/02/05.

49 Alex Kasprak, Environmental Engineer, Massachusetts Turnpike Authority—CA/T Project.

50 Massachusetts Turnpike Authority, "Big Dig: Controlling Diesel Air Pollution." Online resource, available at: http://www.masspike.com/bigdig/background/airpollution.html Last accessed 03/04/05.

51 Alex Kasprak, Guido Schattanek, Ping K. Wan, Emission Reduction Retrofit Program For Construction Equipment Of The Central Artery/Tunnel Project, Paper No. 206, p. 7.

52 For example, visit the EPA Region 8 web site at: http://www.epa.gov/Region2/air/8_2000.pdf and the EPA Office of Transportation and Air Quality web site at: http://www.epa.gov/otaq/retrofit/exbigdig.htm

53 For more information, please contact: Donna Weaver via email at Donna.Weaver@po.state.ct.us or by phone at 860-594-2082.

54 Connecticut Department of Transportation (DOT). "Connecticut Clean Air Construction Initiative." Online resource, available at: http://www.i95newhaven.com/poverview/environ_init.asp For more information please go to another DOT web site at: http://www.i95newhaven.com/poverview/awma_2002_nhhc.pdf and to the Weaver Presentation on the Clean Fleet USA program's web site at: http://www.cleanfleetsusa.net/highlights/present/weaver_present.pdf Contact person: Donna Weaver, Connecticut Department of Transportation; Phone: 860.594.2082.

55 For more information on the Port of Houston Authority's use of cleaner diesel fuels and/or technology, please contact:

Shari Baldridge by phone at 713-670-2428 or via email at sbaldridge@poha.com.

[56] EPA, "Region 6: State Designations." Online resource, available at: http://www.epa.gov/ozonedesignations/regions/region6desig.htm Last accessed 09/11/05.

[57] Ibid, Page 20.

[58] Ibid, Page 23.

[59] Ibid, Page 24.

[60] Ibid, Page 23.

[61] Ibid, Page 24.

[62] *Ibid.*

[63] Ibid, Page 25.

[64] Environmental Protection Agency. "Port of Houston Pilot Retrofit Program." Online resource, available at: http://www.epa.gov/otaq/retrofit/exporthouston.htm Last accessed 03/02/05.

[65] More information on the Puget Sound Clean Air Agency, with contact information, is available at: http://www.pscleanair.org

[66] Based on a conversation with Paul Carr, of the Puget Sound Clean Air Agency on February 28, 2005.

[67] For a directory of TERP contact information, please visit: http://www.tnrcc.state.tx.us/oprd/sips/contact_info.html

[68] Texas Natural Resource Conservation Commission (TNRCC), "What is the TERP?" March 15, 2004. Online resource, available at: http://www.tnrcc.state.tx.us/oprd/sips/overview.html#what_is Last accessed 03/02/05.

[69] TNRCC. "Incentive Grants for Reducing Emissions." August 17, 2004. Online resource, available at: http://www.tnrcc.state.tx.us/oprd/sips/grants.html Last accessed 03/02/05.

[70] EPA, "Voluntary Diesel Retrofit Program: Implementation Progress Update." December 3, 2003. Page 6. Online resource, available at http://www.epa.gov/air/caaac/mstrs/blubaugh_1203.pdf Last accessed 03/02/05.

[71] TCEQ. "Texas Emissions Reduction Plan, Biennial Report to the Texas Legislature." December 2004. Online resource, available at: http://www.tceq.state.tx.us/assets/public/comm_exec/pubs/sfr/079_04.pdf Last accessed 03/02/05.

[72] TCEQ. "FY2004, 1st Round Approved Projects." March 22, 2004. Online resource, available at: http://www.tnrcc.state.tx.us/oprd/sips/grants.html Last accessed 03/02/05.

[73] TCEQ. "Texas Emissions Reduction Plan: FY2004, 2nd Round Application Period" SRP-079/02. December 2002.

[74] TCEQ. "FY 2002-2003 Grants Awarded." March 22, 2002.

[75] TCEQ. "Texas Emissions Reduction Plan, Biennial Report to the Texas Legislature." December 2004. Online resource, available at: http://www.tceq.state.tx.us/assets/public/comm_exec/pubs/sfr/079_04.pdf Last accessed 03/02/05.

[76] For more information about CARB, please contact: Scott Rowland, the CARB Manager of its Retrofit Assessment Section via email at srowland@arb.ca.gov or by phone at 626-575-6972.

[77] Based on phone correspondence with Edie Chang of the California Air Resources Board on September 3, 2004. Or CARB, "The Carl Moyer Program Annual Status Report." February 2004. Online resource, available at: http://www.arb.ca.gov/msprog/moyer/moyer_2004_report.pdf Last accessed 03/23/05.

[78] California Air Resources Board, "AB923—New Funding for the Expanded Carl Moyer Program." October 20, 2004. Online resource, available at: http://www.arb.ca.gov/msprog/moyer/ab923/ab923.htm?PF=Y Last accessed 03/02/05.

[79] Walsh, Michael. "Vehicle Emissions Trends and Forecasts: The Lessons of the Past 50 Years." May 2003. Blue Sky in the 21st Century Conference. Seoul, Korea. Page 10. Online resource, available at: http://www.walshcarlines.com/pdf/vehicle_trends_lesson.cf9.pdf Last accessed 03/01/05.

[80] Block, Michael. *Retrofit Primer—Emission Reduction Technologies and Strategies*. NESCAUM, October 2003. Page 14. Online resource, available at: http://bronze.nescaum.org/retrofitworkshop/folder/Primer.pdf Last accessed 03/01/05.

[81] EPA, "Heavy Trucks, Buses, and Engines." Online resource, available at http://www.epa.gov/otaq/hd-hwy.htm Last accessed 03/01/05.

[82] EPA, "Clean Air Nonroad Diesel—Final Rule" Online resource, available at: http://www.epa.gov/nonroad-diesel/2004fr.htm Last accessed 03/01/05.

[83] EPA. "Fuels Map." Online resource, available at: http://www.epa.gov/otaq/retrofit/fuelsmap.htm Last accessed 03/01/05.

[84] EPA, "Press Release: New Clean Diesel Rule Major Step in a Decade of Progress." May 11, 2004. Online resource, available at: http://yosemite.epa.gov/opa/admpress.nsf/b1ab9f485b098972852562e7004dc686/f20d2478833ea3bd85256e91004d8f90?OpenDocument Last accessed 03/01/05.

[85] STAPPA/ALAPCO (The State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials), "The Dangers of the Dirtiest Diesels: The Health and Welfare Impacts of Nonroad Heavy-Duty Diesel Engines and Fuels," (June 2002), available on-line at: http://www.4cleanair.org/FINALNonroadHDDReport.pdf at 4 & 17. Last accessed 03/01/05.

[86] EPA Clean Diesel Program. Online resource available, at http://www.epa.gov/diesel/ Last accessed on 3/2/05. See also http://www.dieselforum.org/factsheet/ulsd.html.

[87] EPA, "Highway Diesel Progress Report 2—Executive Summary." March 2004. EPA A420-S-04-001. Online resource, available at: http://www.epa.gov/otaq/regs/hd2007/420s04001.htm Last accessed 03/01/05.

[88] EPA, "Clean Air Nonroad Diesel Rule Summary." May 2004. EPA A420-F-04-029. Online resource, available at: http://www.epa.gov/nonroad-diesel/2004fr/420f04029.htm Last accessed 03/01/05.

[89] Lubrizol, "PuriNOx Technology: Understanding the Fuel Emulsion Process." 2004. Online resource, available at: http://www.lubrizol.com/PuriNOx/understand.asp Last accessed 03/01/05.

[90] EPA, "Retrofit Technologies from Lubrizol Corporation." August 5, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/techlist-lubrizol.htm Last accessed 03/01/05.

[91] *Ibid.*

[92] CARB, "Diesel Emissions Control Strategies, Verification Level 2, Verified Technologies. February 23, 2005. Online resource, available at: http://www.arb.ca.gov/diesel/verdev/level2/level2.htm Last accessed 03/01/05.

[93] CARB Diesel Emission Control Strategies Verifications: Online resource, available at: http://www.arb.ca.gov/diesel/verdev/verdev.htm Last accessed 03/01/05. CARB has also verified PuriNOx for 1988 through 2003 model year diesel engines used in on-road applications. PuriNOx is an emulsified diesel fuel which, according to CARB verification, achieves at least 50% reduction in PM and 15% reduction of NO_x. http://www.arb.ca.gov/diesel/verdev/level2/level2.htm Last accessed 03/01/05.

[94] Information provided by Engine Control Systems (ECS). Numbers are based on the use of PuriNOx and ECS's DPF (Purifilter) and DOC (Purimuffler). EPA has verified that ECS's Purifilter reduces PM emission by 90%, HC emissions by 85% and CO emissions by 75%. EPA has verified that ECS's Purimuffler reduces PM emissions by 20%, HC emissions by 50% and CO emissions by 40%. http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm

[95] For more information regarding different applications and test results of emulsified fuels please refer to reports No. 4576-1 (Emulsified Diesel Fuels: Literature Review and Consolidation of Lubrizol Recommendations), 4576-2 (Emulsified Diesel Emission Testing, Performance Evaluation, and Operational Assessment) and 4576-3 (TxDOT Emulsified Diesel Final Report) listed on the webpage of the Center For Transportation Research. http://www.utexas.edu/research/ctr/pdf_reports/index.html#4177-1

[96] Based on e-mail correspondence with Ron Dunfee, of Lubrizol Corporation, on August 30, 2004.

[97] Number provided by Lubrizol manufacturer of PuriNOx.

[98] Lubrizol, "PuriNOx Questions and Answers." Online resource, available at: http://www.lubrizol.com/purinox/purinoxcd/lzquestions.htm Last accessed 03/01/05.

[99] Based on e-mail correspondence with Ron Dunfee, of Lubrizol Corporation, on August 30, 2004.

[100] *Ibid.*

[101] *Ibid.*

[102] Information taken from a fact sheet about Platinum Plus DFX by Clean Diesel Technologies, Inc.

[103] FBC called Platinum Plus® sold by Clean Diesel Technologies, Inc. Please refer to Appendix A for contact information. EPA, "Verified Products." August 11, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Last accessed 03/01/05.

[104] Based on phone conversation with Glen Reid of Clean Diesel Technologies, Inc. on July 6, 2004.

[105] World Health Organization. "Air Quality Guidelines: Chapter 6.11 Platinum." Second Edition, 2000. Online resource, available at: http://www.euro.who.int/document/aiq/6_11platinum.pdf Last accessed 03/01/05.

[106] United Kingdom Department of Health. "1996 Report of the Committees on Toxicity, Mutagenicity, Carcinogenicity of Chemicals in Food, Consumer Products, and the Environment." January 29, 1998. Online resource, available at: http://www.archive.official-documents.co.uk/document/doh/toxicity/chap-1b.htm Last accessed 03/01/05.

[107] Stricklin Company offers a FBC called Blue Marble(tm). However, Blue Marble(tm) has not yet been EPA verified. According to the Strickling webpage, Blue Marble™ products contain Phosfamid™, an advanced metal treatment that causes metal, according to Stricklin, to become smoother, shinier and resistant to carbon buildup. Distributed by The Stricklin Companies, 1415 Stratford Crt., Del Mar, CA 92014, Ph: 858-794-5700, Fax: 848-794-2666, email: stricklin@worldnet.att.net See also: The Stricklen Companies, "Blue Marble Applications/ Engine Test Results." Online resource, available at: http://www.phosfamid.com/html/applications/index.html#HongKongPolytechnicUniversity Last accessed 03/01/05.

[108] National Biodiesel Board. "Biodiesel 2001." 2001. Online resource, available at: http://www.investingdd.com/pdfs/backgrounder.pdf Last accessed 03/01/05.

[109] EPA, "Draft Technical Report: A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions." *EPA-420-P-02-001, October 2002.*

[110] In a study of the effects of Biodiesel on greenhouse gas emissions, the U.S. EPA reports: "we cannot confidently conclude the Biodisel increases or decreases CO_2 emissions." Environmental Protection Agency. "A Comprehensive Analysis of Biodiesel Impacts on Exhaust Emissions." *EPA-420-P-02-001*, October 2002. Page 50. Online resource, available at: http://www.epa.gov/otaq/models/analysis/biodsl/p02001.pdf Last accessed 03/01/05.

[111] See also *Ibid.*

[112] EPA, "Retrofit Technologies - Biodiesel." June 10, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/techlist-biodiesel.htm Last accessed 03/01/05.

[113] *Ibid,* page 46.

[114] National Biodeisel Board, "Biodeisel Emissions." Online resource, available at: http://www.biodiesel.org/pdf_files/emissions.pdf Last accessed 03/01/05.

[115] *Ibid.*

[116] EPA, "Clean Alternative Fuels: Compressed Natural Gas." EPA 420-F-00-033. March 2002. Online resource, available at: http://www.epa.gov/otaq/consumer/fuels/altfuels/420f00033.pdf Last accessed 03/01/05.

[117] In fact, Waste Management Inc. operates approximately 125 CNG fueled heavy-duty trucks. U.S. Dept. of Energy, "Waste Management, Inc." August 25, 2003. Online resource, available at: http://www.eere.energy.gov/cleancities/progs/new_success_ddown.cgi?110 Last accessed 03/01/05.

[118] U.S. Department of Energy: Alternative Fuel Data Center. Online resource, available at: http://www.eere.energy.gov/afdc/altfuel/natural_gas.html Last accessed 03/01/05.

[119] For example, Waste Management Inc. in California is currently converting old Mack MR trucks to run on LNG and is also buying new LNG-fueled vehicles. Waste Management's fleet includes more than 235 heavy-duty trucks powered by LNG. U.S. Dept. of Energy, "Waste Management, Inc." August 25, 2003. Online resource, available at: http://www.eere.energy.gov/cleancities/progs/new_success_ddown.cgi?110 Last accessed 03/01/05.

[120] EPA, "Clean Alternative Fuels: Propane." March 2002. EPA 420-F-00-039. Online resource, available at: http://www.epa.gov/otaq/consumer/fuels/altfuels/420f00039.pdf Last accessed 03/01/05.

[121] U.S. DOE, "Propane Vehicles." July 21, 2004. Online resource, available at: http://www.eere.energy.gov/afdc/afv/prop_vehicles.html Last accessed 03/04/05.

[122] U.S. Department of Energy: Alternative Fuel Data Center. Online resource, available at: http://www.eere.energy.gov/afdc/altfuel/prop_benefits.html Last accessed 03/01/05.

[123] MECA, "MECA supports U.S. EPA Proposal to Reduce Emissions from Nonroad Diesel Engines and Equipment." April 15, 2003. Online resource, available at: http://www.meca.org/jahia/Jahia/engineName/filemanager/pid/226/EPAnonroadNPRMpr

041503.pdf?actionreq=actionFileDownload &fileItem=500 Last accessed 03/03/05.

[124] *Ibid.*

[125] *Ibid.*

[126] Timothy V. Johnson, "Is there a simple solution for the diesel emission control challenge?" *Environmental Technologies,* January 2004. Volume 25 No. 2. Online resource, available at: http://www.corning.com/environmentaltechnologies/emissions_control_technology_magazine/article2.asp Last accessed 03/03/05.

[127] *Ibid.*

[128] EPA, "Voluntary Diesel Retrofit Program" Office of Transportation and Air Quality. Online resource, available at http://www.epa.gov/otaq/retrofit Last accessed 03/03/05.

[129] For an overview of different retrofit devices, please also refer to: Joe Kubsch. *Retrofit Emission Control Technologies for Diesel Engine,* MECA, November 4, 2003. Online resource, available at: http://www.4cleanair.org/JoeKubsh.pdf Last accessed 08/13/04.

[130] "Verified" means that either the EPA or the California ARB have verified this type of technology. However, please refer to http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm and http://www.arb.ca.gov/diesel/verdev/verdev.htm for detailed information regarding the different types of verified emission control technologies and the different manufacturers whose technologies have been verified.

[131] EPA, "Voluntary Diesel Retrofit Program: Glossary" Office of Transportation and Air Quality. Online resource, available at http://www.epa.gov/otaq/retrofit/glossary.htm Last accessed 03/03/05.

[132] EPA, "Diesel Particulate Matter (PM) Filter Overview." Office of Transportation and Air Quality, February 13, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/documents/bigdig_case_08.htm Last accessed 03/03/05.

[133] EPA's verified level of reduction for Johnson Matthey Continuously Regenerating Technology (CRT). EPA, "Verified Products." August 11, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Last accessed 03/03/05.

[134] Kodjak et al., Attachment D, "The Clean Air Construction Initiative, Diesel Particulate Filters Technology Description and Overview of Operational Issues"

[135] Information provided by Johnson Matthey.

[136] Joe Kubsch. *Retrofit Emission Control Technologies for Diesel Engine,* MECA, November 4, 2003. Online resource, available at: http://www.4cleanair.org/JoeKubsh.pdf Last accessed 03/03/05.

[137] *Ibid.*

[138] "Verified" means that either the EPA or the California ARB have verified this type of technology. However, please refer to http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm and http://www.arb.ca.gov/diesel/verdev/verdev.htm for detailed information regarding the different types of verified emission control technologies and the different manufacturers whose technologies have been verified.

[139] Block, Michael. *Retrofit Primer—Emission Reduction Technologies and Strategies.* NESCAUM, October 2003. Page 10. Online resource, available at: http://bronze.nescaum.org/retrofitworkshop/folder/Primer.pdf Last accessed 03/03/05.

[140] California Air Resource Board, "Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles", October 2000, p. 19.

[141] Johnson Matthey's CRT and CCRT. For more information, visit the Johnson Matthey Catalyst web site at: http://www.jmcatalysts.com Last accessed 03/03/05.

[142] "Verified" means that either the EPA or the California ARB have verified this type of technology. However, please refer to http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm and http://www.arb.ca.gov/diesel/verdev/verdev.htm for detailed information regarding the different types of verified emission control technologies and the different manufacturers whose technologies have been verified.

[143] Rypos Inc., "Company Info." Online resource, available at: http://www.rypos.com/html/companyinfo.html Last accessed 03/03/05. For examples where Rypos' DPF (Rypos Trap) have been used, visit the Rypos web site at: http://www.rypos.com/html/index.html. DCL International Inc. also sells active DPFs.

[144] Rypos Inc.s' Active DPF does not require the use of ULSD. Online resource, available at: http://www.rypos.com/html/products.html Last accessed 03/03/05.

[145] California Air Resources Board, "Diesel Emission Control Strategies Verification:

Level 3 Verified Technologies." 01.25.2005. Online resource, available at: URL: http://www.arb.ca.gov/diesel/verdev/level3.htm Last accessed 03/03/05.

[146] "Verified" means that either the EPA or the California ARB have verified this type of technology. However, please refer to http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm and http://www.arb.ca.gov/diesel/verdev/verdev.htm for detailed information regarding the different types of verified emission control technologies and the different manufacturers whose technologies have been verified.

[147] FBC called Platinum Plus(r) and CWMF both sold by Clean Diesel Technologies, Inc. Please refer to Appendix A for contact information. EPA, "Verified Products." August 11, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Last accessed 08/13/04.

[148] Based on phone conversation with Glen Reid of Clean Diesel Technologies, Inc. on July 6, 2004.

[149] EPA, "Verified Products." June 21, 2005. Online resource, available at: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Last accessed 08/03/05.

[150] Based on phone conversation with Glen Reid of Clean Diesel Technologies, Inc. on July 6, 2004.

[151] Based on email correspondence with Glen Reid of Clean Diesel Technologies, Inc. on August 3, 2004.

[152] Based on email correspondence with Glen Reid of Clean Diesel Technologies, Inc. on August 27, 2004.

[153] Sold in the U.S. by Clean Air Power (see Appendix A for contact information).

[154] Based on phone conversation with Clean Air Power. 08/25/04.

[155] The certification was done by AVL, an engine testing center in Sweden. The AVL web site is available at: http://www.mtc.se/eng/content/aboutmtc.htm

[156] The Swiss verification is referred to as "VERT" verification. For more information, please visit: http://www.umwelt-schweiz.ch/buwal/eng/fachgebiete/fg_luft/vorschriften/industrie_gewerbe/filter/index.html

[157] EPA, "Terms of Environment." Online resource, available at: http://www.epa.gov/OCEPAterms/oterms.html Last accessed 03/03/05.

[158] Information provided by Clean Air Power by e-mail.

[159] "Verified" means that either the EPA or the California ARB have verified this type of technology. However, please refer to http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm and http://www.arb.ca.gov/diesel/verdev/verdev.htm for detailed information regarding the different types of verified emission control technologies and the different manufacturers whose technologies have been verified.

[160] Block, Michael. *Retrofit Primer—Emission Reduction Technologies and Strategies.* NESCAUM, October 2003. Page 5. Online resource, available at: http://bronze.nescaum.org/retrofitworkshop/folder/Primer.pdf Last accessed 03/03/05.

[161] Philadelphia Diesel Difference, Diesel Oxidation Catalyst. Online resource, available at: http://www.cleanair.org/dieseldifference/retrofits/ Last accessed 03/03/05.

[162] Diesel Emission Evaluation Program, DEEP. Online resource, available at: http://www.deep.org/reports/sum_gloss.pdf. Last accessed 03/03/05. Also refer to DieselNet. Online resource, available at: http://www.dieselnet.com/gl-s.html Last accessed 03/03/05.

[163] Block, Michael. *Retrofit Primer—Emission Reduction Technologies and Strategies.* NESCAUM, October 2003. Page 5. Online resource, available at: http://bronze.nescaum.org/retrofitworkshop/folder/Primer.pdf Last accessed 03/03/05.

[164] *Ibid.*

[165] *Ibid.*

[166] EPA's verified level of reduction for numerous suppliers of catalyst muffler products. EPA, "Verified Products." August 11, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Last accessed 03/03/05.

[167] Joe Kubsch. *Retrofit Emission Control Technologies for Diesel Engine,* MECA, November 4, 2003. Online resource, available at: http://www.4cleanair.org/JoeKubsh.pdf. Last accessed 03/03/05.

[168] Information based on phone conversation with Alex Kasprak of the Big Dig Project on June 18, 2004.

[169] Information based on Donaldson letter to Environmental Defense dated March 25, 2004.

170 Information based on e-mail correspondence with Fred Schmidt of Donaldson Company, Inc. on November 1, 2004.

171 EPA, "Verified Products." August 11, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Last accessed 03/03/05.

172 Information provided by Donaldson Brochure for Spiracle Filtration Systems.

173 Information based on e-mail correspondence with Fred Schmidt, of Donaldson Company, Inc. on October 26, 2004.

174 California Air Resources Board. "The Carl Moyer Memorial Air Quality Standards Attainment Program Guidelines: Approved Revision 2003." September 30, 2003. Page 6. Online resource, available at: http://www.arb.ca.gov/msprog/moyer/2003moyerguide.pdf Last accessed 03/03/05.

175 Texas State House of Representatives. "House Bill 1365." §8(a) Effective 06/22/03. Online resource, available at: http://www.capitol.state.tx.us/cgi-bin/tlo/textframe.cmd?LEG=78&SESS=R&CHAMBER=H&BILLTYPE=B&BILLSUFFIX=01365&VERSION=5&TYPE=B Last accessed 03/03/05.

176 Except for Extengine's ADEC system (see 3.1), no mobile SCR system has been EPA or CARB verified as of February 11, 2005.

177 A reductant is a substance that is oxidized in the course of reduction. It is a reducing agent that chemically reduces other substances. Here, the reducing agent is urea or ammonia, which chemically reduces NO_x into N_2.

178 Emissions reduction with use of 30ppm low sulfur fuel. Khair, Magdi. "Integration of EGR, SCR, DPF, and fuel-borne catalyst for NO_x/PM reduction," Oct. 1999. According to Argillon LLC, their SCR reduces 60% of soluble organic fraction of PM and up to 90% NO_x depending on the application (average between 60-80% NO_x reduction).

179 Block, Michael. *Retrofit Prime—Emission Reduction Technologies and Strategies.* NESCAUM, October 2003. Page 13. Online resource, available at: http://bronze.nescaum.org/retrofitworkshop/folder/Primer.pdf Last accessed 03/03/05.

180 For example, the Argillon mobile SCR is equipped with such a remote data-recording device.

181 Information based on phone conversation with T.J. Tarabulski of Combustion Components Associates Inc. on February 11, 2005. Reference is also made to: http://www.extengine.com/index.html Last accessed 03/03/05.

182 *Retrofit Emission Control Technologies for Diesel Engine,* Joe Kubsh, MECA, November 4, 2003. Joe Kubsch. *Retrofit Emission Control Technologies for Diesel Engine,* MECA, November 4, 2003. Online resource, available at: http://www.4cleanair.org/JoeKubsh.pdf Last accessed 03/03/05.

183 Combustion Component Association Inc. has installed mobile SCR units in seven big earth moving construction vehicles (four scrapers, one rubber-tire dozer, one motor grader, one waterpull and one watertruck) in Palm Desert, CA). Information provided by Combustion Components Associates Inc.

184 Based on a phone conversation with T.J. Tarabulski of Combustion Components Associates Inc. on February 11, 2005.

185 DieselNet, "EMA Releases Urea-SCR Infrastructure Study." Oneline resource, available at: http://www.dieselnet.com/news/0308ema.html Last accessed August 3, 2005.

186 Combustion Components Associates, Inc, "ELIM-NOx: A Mobile Diesel NO_x Emissions Reduction System." Online resource, available at: http://www.combustioncomponents.com/images/mobilescr/mobilescr.pdf Last accessed 03/03/05.

187 Based on a phone conversation with T.J. Tarabulski of Combustion Components Associates Inc. on February 11, 2005.

188 These numbers do not include installation and tax. Installation costs run usually between 20–30% of unit price. NO_x reduction level: 60-90% depending on catalyst volume, baseline NO_x levels and exhaust temperatures. Information provided by Clean Diesel Technologies, Inc. and Argillon LLC.

189 Information provided by Argillon LLC.

190 Lexico Publishing, LLC "Dictionary: Adsorb." Online resource, available at: http://dictionary.reference.com/search?q=adsorb. Last accessed 04/05/05.

191 CARB, "Appendix B: Diesel Engine Emission Control Technologies." Online resource, available at: http://www.arb.ca.gov/regact/dieselrv/appb.doc. Last accessed 04/05/05.

192 Jim Parks et al., "DeSulfation of NO_x Adsorbers: Studies with the SpaciMS

Technique." 7th Diesel Engine Emissions Reduction Workship. Portsmouth, Virginia. August 5–9, 2001. Online resource, available at: http://www.osti.gov/fcvt/deer2001/parks .pdf Last accessed 03/03/05.

193 Manufacturers of Emission Controls Association, "Catalyst-Based Diesel Particulate Filters and NO_x Adsorbers: A Summary of the Technologies and the Effects of Fuel Sulfur." August 14, 2000. Online resource, available at: http://www.cleanairnet.org/infopool/1411/articles-35627_catalystbased _diesel.pdf Last accessed 03/03/05.

194 Bruce Bertelsen, "Reducing Emissions from Existing Diesel Engines: The Critical Role of Diesel Retrofit Technologies: Background Document." Environmental & Energy Technology and Policy Institute. January 15–16, 2004. Online resource, available at: http://embarq.wri.org/documents/hittingtheroad/bertelsen.pdf Last accessed 03/03/05.

195 Manufacturers of Emission Controls Association, "Catalyst-Based Diesel Particulate Filters and NO_x Adsorbers: A Summary of the Technologies and the Effects of Fuel Sulfur." August 14, 2000. Page 17. Online resource, available at: http://www.cleanairnet .org/infopool/1411/articles-35627 _catalystbased_diesel.pdf Last accessed 03/03/05.

196 Catalytica Energy Systems, "Diesel NO_x Reduction." Online resource, available at: http://www.catalyticaenergy.com/new_technologies/diesel.htm#Retrofit Last accessed 03/03/05.Catalytica is also working to develop NO_x adsorber technology for stationary diesel engines that will produce a 90% reduction in NO_x emissions in both new and retrofitted engines.

197 Manufacturers of Emission Controls Association, "Catalyst-Based Diesel Particulate Filters and NO_x Adsorbers: A Summary of the Technologies and the Effects of Fuel Sulfur." August 14, 2000. Page 17. Online resource, available at: http://www.cleanairnet .org/infopool/1411/articles-35627 _catalystbased_diesel.pdf Last accessed 03/03/05.

198 "Verified" means that either the EPA or the California ARB have verified this type of technology. However, please refer to http://www.epa.gov/otaq/retrofit/retroverifiedlist .htm and http://www.arb.ca.gov/diesel/verdev/verdev.htm for detailed information regarding the different types of verified emission control technologies and the different manufacturers whose technologies have been verified.

199 Bruce Bertelsen, "Reducing Emissions from Existing Diesel Engines: The Critical Role of Diesel Retrofit Technologies: Background Document." Environmental & Energy Technology and Policy Institute. January 15–16, 2004. Online resource, available at: http://embarq.wri.org/documents/hittingtheroad/bertelsen.pdf Last accessed 03/03/05.

200 Paul W. Park, "Correlation Between Catalyst Surface Structure and Catalyst Behavior: Selective Catalytic Reduction with Hydrocarbon." May 21, 2002. EMSL 2002. Richland, Washington. Online resource, available at: http://www.emsl.pnl.gov/new/emsl2002/abstracts/park.doc Last accessed 03/03/05.

201 Diesel Technology Forum, "Engineering Clean Air: The Continuous Improvement of Diesel Engine Emission Peformance." March, 2001. Page 13. Online resource, available at: http://www.dieselforum.org/whitepaper/downloads/DTF-Continuous Improvement03-01.pdf Last accessed 03/03/05.

202 Carrie Boyer et al., "Lean NO_x Catalysis: Research and Development." Caterpillar, Inc. Online resource, available at: http://www.orau.gov/deer/DEER2003/presentations/session11/3.%20Endicott%20-%20 DEER_2003_Final_Lean-NOx.pdf Last accessed 03/03/05.

203 EPA, "Technical Summary." Online Resource, available at: http://www.epa.gov/otaq/retrofit/retropotentialtech.htm Last accessed 03/03/05.

204 *Ibid.*

205 Cleaire's "Longview" filter reduces 25% NO_x and 85% PM. The Longview filter has been CARB verified for onroad. Cleaire Inc, "Products." Online resource, available at http://www.cleaire.com/site/products/# Last accessed 03/03/05. Extengine's ADEC system reduces PM, HC, CO and NO_x by approx. 75%. CARB nonroad verification is pending (as per August 2004). Extengine, "ADEC Advanced Diesel Emission Control system." Online resource, available at: http://www.extengine.com/adec.html Last accessed 03/03/05.

206 As of February 11, 2005, only the ADEC system has been verified, Johnson Matthey's SCRT is still in development and undergoing field testing.

[207] Extengine, "ARB Verifies Retrofit System to Reduce Diesel Exhaust on Older Off-Road Equipment." Online resource, available at: http://www.extengine.com/index.html Last accessed 03/03/05.

[208] California Air Resources Board, "Diesel Emission Control Strategies Verification: Level 1 Verified Technologies." 01.27.2005. Online resource, last accessed 02.04.2005. URL: http://www.arb.ca.gov/diesel/verdev/level1.htm

[209] Letter from Steve B. Dornak (Mayor's Office of the City of Houston) to Annette Herbert of CARB, dated July 15, 2004 stating, in part, the following: "Field tests of the Extengine ADEC system were the most impressive. Testing of the ADEC I and II systems produced CO reductions of 76 to 84%, while NO_x reduction of 78 to 82% were observed."

[210] Based on e-mail correspondence with Phillip Roberts, of Extengine, on 01.23.2005.

[211] A Slip Catalyst converts excessive ammonia into nitrogen and water to avoid ammonia being emitted through the exhaust gas. Information based on phone conversation with T.J. Tarabulski of Combustion Components Associates Inc. on February 11, 2005.

[212] *Ibid.*

[213] Johnson Matthey, "Johnson Matthey Introduces the SCRT System." Online resource, available at: http://www.jmcsd.com/scrttm_system.html Last accessed 03/03/05.

[214] Marty Lassen, "EPA Clean Diesel Engine Implementation Workshop." Johnson Matthey, August 6-7, 2003. Online resource, available at: http://www.epa.gov/otaq/regs/hd2007/wrkshop2/lassen.pdf, please see slide 5. Last accessed 03/03/05.

[215] "Verified" means that either the EPA or the California ARB have verified this type of technology. However, please refer to http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm and http://www.arb.ca.gov/diesel/verdev/verdev.htm for detailed information regarding the different types of verified emission control technologies and the different manufacturers whose technologies have been verified.

[216] EPA and CARB have signed a Memorandum of Agreement for the Coordination and Reciprocity in Diesel Retrofit Device Verification.

[217] CARB, "Diesel Emissions Control Strategies Verification: Level 3 Verified Technologies." Online resource, available at: http://www.arb.ca.gov/diesel/verdev/level3.htm Last accessed 03/03/05.

[218] Cleaire Inc, "Products." Online resource, available at http://www.cleaire.com/site/products/# Last accessed 03/03/05.

[219] Longview filters have been installed on motor graders, wheel loaders, backhoe loaders and backup generators.

[220] Only once in a very unusual application could the exhaust gas temperature not be achieved. Information based on phone conversation with Tim Taylor of Cleaire on August 3, 2004.

[221] Pricing can vary depending on the distributor.

[222] These numbers include installation and tax. Numbers provided by Cleaire, Inc.

[223] Information based on e-mail correspondence with Tim Taylor, of Cleaire Advanced Emission Controls, LLC on February 18, 2005.

[224] *Ibid.*

[225] Cleaire Inc, "Products." Online resource, available at http://www.cleaire.com/site/products/# Last accessed 03/03/05.

[226] Information based on e-mail correspondence with Tim Taylor, of Cleaire Advanced Emission Controls, LLC on February 18, 2005.

[227] Numbers include installation and tax. Numbers provided by Cleaire, Inc. However, pricing can vary depending on the distributor.

[228] This section is from Retrofitting Emission Controls On Diesel-Powered Vehicles. MECA, March 2002. Online resource, available at http://www.meca.org/jahia/Jahia/engineName/filemanager/pid/229/dieselretrofitwp.pdf?actionreq=actionFileDownload&fileItem=220 Last accessed 03/03/05.

[229] MECA Diesel Retrofit. Frequently Asked Questions About The Installation Of Emission Controls On Existing Diesel Engines, page 3. Online resource, available at: http://www.meca.org/jahia/Jahia/engineName/filemanager/pid/224/retrofitFAQ%20(revised).pdf?actionreq=actionFileDownload&fileItem=712 Last accessed 03/03/05.

[230] Based on a telephone conversation with Alex Gorrel of SST Emtec on October 5, 2004.

[231] Based on a telephone conversation with Alex Gorrel of SST Emtec on October 5, 2004.

[232] CARB, "Carl Moyer Third Year Status Report." March 26, 2002. Online resource, available at: http://www.arb.ca.gov/msprog/moyer/2002report.pdf Last accessed 03/01/05.

[233] CARB, "The Carl Moyer Program Annual Status Report." February 2004. Online resource, available at: http://www.arb.ca.gov/msprog/moyer/moyer_2004_report.pdf Last accessed 03/01/05

[234] CARB, "Carl Moyer Program Update." January 20, 2005. Online resource, available at: http://www.arb.ca.gov/msprog/moyer/carl_moyer_board_presentation_1_20_05.pdf Last accessed 03/01/05.

[235] *Ibid.*

[236] *Ibid.*

[237] California State Legislature, "Assembly Bill 932, Chapter 707." September 23, 2004. Online resource, available at: http://www.arb.ca.gov/msprog/moyer/ab923/ab923text.pdf Last accessed 03/01/05.

[238] CARB, "Carl Moyer Program Update." January 20, 2005. Online resource, available at: http://www.arb.ca.gov/msprog/moyer/carl_moyer_board_presentation_1_20_05.pdf Last accessed 03/01/05.

[239] California State Legislature, "Assembly Bill 932, Chapter 707." September 23, 2004. Online resource, available at: http://www.arb.ca.gov/msprog/moyer/ab923/ab923text.pdf Last accessed 03/01/05.

[240] *Ibid.*

[241] NCDAQ, "2004 Grant Awards." 09/21/2004. Online resource, available at: http://daq.state.nc.us/motor/ms_grants/grant04.shtml Last accessed 03/01/05.

[242] Texas Natural Resource Conservation Commission (TNRCC). http://www.tnrcc.state.tx.us/oprd/sips/terp.html

[243] TCEQ, "Texas Emissions Reduction Plan: Biennial Report to the Legislature." December 2004. Online resource, available at: http://www.tceq.state.tx.us/assets/public/comm_exec/pubs/sfr/079_04.pdf Last accessed 03/01/05.

[244] Texas Legislature, House Bill 2481, 2005.

[245] For the EPA onroad retrofit technology verification program, visit: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Last accessed 08/13/04. For the CARB onraod retrofit technology verification program, visit: http://www.arb.ca.gov/diesel/verdev/background.htm Last accessed 08/13/04.

[246] EPA, "Verified Products." August 11, 2004. Online resource, available at: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm Last accessed 08/13/04.

[247] *Ibid.*

[248] CARB, "Diesel Emission Control Strategies Verification: Background." April 15, 2003. Online resource, available at: http://www.arb.ca.gov/diesel/verdev/background.htm Last accessed 08/13/04.

[249] EPA, "What is a State Implementation Plan?" Online resource, available at: http://www.epa.gov/region1/topics/air/sips/REVISED_WHAT_IS_A_SIP.pdf Last accessed 03/02/05.

[250] EPA, "8-Hour Ground-level Ozone Designations." March 3, 2005. Online resource, available at: http://www.epa.gov/ozonedesignations Last accessed 03/03/05.

[251] EPA, "EPA Announces Final Designations For First Fine Particle Standards." December 17, 2004. Online resource, available at: http://yosemite.epa.gov/opa/admpress.nsf/b1ab9f485b098972852562e7004dc686/bc63cfdda235542585256f6d005e6738!OpenDocument Last accessed 03/03/05.

[252] EPA, "Regions." Online resource, available at: http://www.epa.gov/epahome/locate2.htm Last accessed 03/03/05.

[253] For Regional EPA Contact Information go to: http://www.epa.gov/otaq/retrofit/cont_eparegions.htm

[254] EPA. *Air and Radiation. Heavy-duty Diesel Emission Reduction Project Retrofit/Rebuild Component.* Prepared by Northeast States for Coordinated Air Use Management. EPA420-R99-014. June 1999.

[255] Based on E-mail correspondence with U.S. EPA, January 26, 2005. Also refer to: Calculating SIP credits. Online resource, available at: http://www.epa.gov/otaq/retrofit/aqsipcalc.htm Last accessed 03/03/05.

[256] EPA Clean Diesel Program. Online resource available, at http://www.epa.gov/diesel/ Last accessed on 03/02/05. See also http://www.dieselforum.org/factsheet/ulsd.html.

[257] Final Rule: "Control of Emissions of Air Pollution from Nonroad Diesel Engines and Fuel" (June 29, 2004): http://www.epa.gov/nonroad-diesel/2004fr.htm#finalrule Last accessed 03/02/05.

[258] New York, NY, Local Law 77, §2(f)(1) (2003). Available online at: http://www.nyccouncil.info/pdf_files/bills/law03077.pdf Last accessed 03/02/05.

[259] *Ibid.*

[260] S. 7652, 227th Leg., (NY. 2004); A. 11716-A, 227th Leg., (NY. 2004).

[261] Sacramento Ozone Summit, "Proactive 'green' contracting by government agencies." Version 13. Online resource, available at: http://airquality.org/modelord/EpisodicModelGreenContractingV13.pdf Last accessed 03/02/05.

[262] The Contract Specification also contin exceptions to idling limits. Those exceptions exist when (a) when a "mobile source" is forced to remain motionless because of traffic conditions or mechanical difficulties over which the "operator" has no control; (b) when it is necessary to operate heating, cooling or auxiliary equipment installed on the "mobile source" when such equipment is necessary to accomplish the intended use of the "mobile source"; (c) to bring the "mobile source" to the manufacturer's recommended operating temperature; (d) when the outdoor temperature is below twenty (20) degrees Fahrenheit; and/or (e) when the "mobile source" is being repaired.

[263] Available online from the NY Department of Transportation's web site, at: http://www.route9a.info/dseis.htm Last accessed 08/25/04.

[264] NY Department of Transportation, "Route 9A Project DSEIS." Online resource, available at: http://www.route9a.info/files/dseis/ch_09/09_air.pdf Last accessed 03/02/05.

[265] Available online from the Metropolitan Transportation Authority, at: http://www.mta.nyc.ny.us/capconstr/fstc/deis.htm Last accessed 03/02/05.

[266] MTA, "Fulton Street DEIS." Online resource, available at: http://www.mta.nyc.ny.us/capconstr/fstc/documents/deis/chapters/ch12.pdf Last accessed 03/02/05.

[267] LAX Coalition for Economic, Environmental, and Educational Justice, "What is a Community Benefits Agreement?" Online resource, available at: http://www.environmentaldefense.org/documents/4172_LAX_CBAbackground.pdf Last accessed 03/02/05.

e

environmental defense

finding the ways that work

National headquarters
257 Park Avenue South
New York, NY 10010
212-505-2100

1875 Connecticut Avenue, NW
Washington, DC 20009
202-387-3500

5655 College Avenue
Oakland, CA 94618
510-658-8008

2334 North Broadway
Boulder, CO 80304
303-440-4901

2500 Blue Ridge Road
Raleigh, NC 27607
919-881-2601

44 East Avenue
Austin, TX 78701
512-478-5161

18 Tremont Street
Boston, MA 02108
617-723-5111

Project Office
3250 Wilshire Boulevard
Los Angeles, CA 90010
213-386-5501