



Heavy-Duty Diesel Emission Reduction Project Retrofit/Rebuild Component

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Use of Urban Bus Program Retrofit/Rebuild Equipment and Third Party Verification System and Model State Policies for the Retrofit/Rebuild of Heavy-Duty Diesel Engines

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Regional and State Programs Division
Office of Mobile Sources
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Prepared for EPA by
NESCAUM
Northeast States for Coordinated Air Use Management

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Northeast States for
Coordinated Air Use
Management

NESCAUM



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NESCAUM Recommendations for
Use of Urban Bus Program
certified retrofit/rebuild equipment
and
Third party verification system
and
Model state policies
for
The Retrofit/Rebuild of Heavy-Duty Diesel Engines

March 1999

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Table of Contents

Executive Summary	ES-1
Introduction	1
A. Background.....	1
B. Project Objective.....	2
C. Project Participants.....	2
I. Use of Federal Urban Bus Program Certified Technologies in Heavy-Duty Engines Not Affected by the Federal Urban Bus Program	3
A. Recommendations for Use of Oxidation Catalysts Certified with the Urban Bus Program Use in Heavy-Duty Engines.....	3
B. Available Data on Emission Reductions from Oxidation Catalysts.....	4
C. Engine Specific Technologies Certified with the Urban Bus Program.....	8
D. Accuracy of Expected Emission Reduction Estimates.....	8
II. Third Party Verification	11
A. Third Party Verification Structure.....	11
B. Role of Third Party Verifier.....	14
III. Testing Requirements	18
A. Establishing Emission Reduction Potential (verification data).....	18
B. In-use testing requirements.....	18
IV. Protocol for Calculating SIP Credits	24
A. Retrofit Website.....	24
B. SIP Credit Calculation Procedure.....	28
C. Baseline and Post-Baseline Emission Rates.....	29
D. Methods for SIP Credit Calculation.....	30
E. Credit Calculation Formulas.....	30
V. Model State Guidance Policies	35
A. Highway Vehicle Retrofit Strategies.....	39
B. Nonroad Retrofit Strategies.....	56
C. Funding Opportunities for Promoting the Retrofit of HD Engines.....	76

List of Tables & Charts

Table 1-1 Equipment Certified & Status of Notifications of Intent

	to Certify Urban Bus Equipment.....	5
Table 1-2	Summary of Available Data for Oxidation Catalyst Use in HDD	6
Table III-1	Detail of Requirements for Retrofit Technologies	22-23
Table V-1	Gasoline School Bus NOx Emissions in the NESCAUM Region.....	44
Table V-2	Cost Effectiveness of TWC NOx Credit Generation.....	44
Table V-3	1998 NESCAUM Region Construction Equipment Emissions	61
Table V-4	U.S. Primary Pollutant Emissions from Diesel Marine Engines.....	66
Table V-5	Proposed EPA Emissions Standards for Marine Vessels	67
Table V-6	Vessel Types in Boston Harbor.....	68
Table V-7	SCR Use in Marine Vessels Worldwide.....	69
Table V-8	Proposed Emissions Performance Standard.....	71
Table V-9	Costs of SCR Retrofit.....	72

List of Figures

	Retrofit/Rebuild Program Flowchart.....	13
Figure One	National Bus Population.....	40
Figure Two	Boston Harbor Marine Vessel NOx Emissions by Vessel Type.....	68

Executive Summary

The purpose of this document is to expand the use of retrofit pollution control technologies in heavy-duty engines through the development of consistent guidelines for voluntary retrofit programs. Such programs would be targeted to heavy-duty vehicles not affected by the federal Urban Bus Program and would include control technologies not certified under that program as well as Urban Bus Program certified technologies. Specifically, this document recommends 1) a protocol for calculating state implementation plan (SIP) credits for voluntary retrofit projects; 2) the structure of a third party retrofit verification system for retrofit technologies; and 3) an in-use testing program to ensure that emission reduction credits claimed are achieved in the field. The last chapter of this document outlines model state policies to reduce heavy-duty engine pollution through retrofit initiatives.

This effort builds on the above mentioned United States Environmental Protection Agency (EPA) initiative begun in 1993 to reduce urban residents' exposure to diesel exhaust, the Urban Bus Retrofit/Rebuild program. The program requires that urban buses operating in metropolitan areas with populations over 750,000 be equipped with EPA certified retrofit pollution control devices such as oxidation catalysts or be rebuilt using certified low emission components at the time of engine overhaul. To date, approximately 10,000 of 42,000 eligible urban buses have been retrofitted or rebuilt as a result of the program. Two states, New Jersey and California, have undertaken retrofit programs or guidelines as well. These efforts are intended to expand the significant emission reductions gained through the federal Urban Bus Program by promoting the use of pollution reducing technologies on the existing heavy-duty fleets in those states.

The need for reducing emissions from the nation's in-use heavy-duty diesel fleets is clear. Current inventories estimate that heavy duty engine emissions comprise 33% of all nitrogen oxides (NOx) pollution and 80% of all particulates (PM) from mobile sources in the Northeast states.¹ Emissions from these engines contribute to serious air pollution problems in the region. NOx causes eutrophication of lakes and streams, acid rain, and is a precursor to ozone which aggravates lung disease. Hydrocarbon (HC) emissions are also ozone precursors and are made up, in part, of toxic substances such as benzene, toluene, and 1,3 butadiene, some of which are known carcinogens. PM emissions are very high from diesel engines and are known to aggravate lung diseases such as asthma, emphysema, and bronchitis. In addition, PM has been labeled a probable human carcinogen by EPA and a toxic air contaminant by the California Air Resources Board. In order for states to achieve air quality goals, significant reductions in heavy-duty diesel emissions will need to be made.

¹ "Heavy-Duty Engine Emissions in the Northeast" NESCAUM May, 1997.

The recommendations contained in this document are based on discussions of a workgroup organized by the Northeast States for Coordinated Air Use Management (NESCAUM). The workgroup was created to provide guidance to state and local agencies, as well as to private organizations that plan to retrofit heavy-duty diesel vehicles with pollution control devices. It included input from state and federal agency staff, testing laboratories, and control equipment manufacturers. In addition, a draft of these guidelines was distributed to EPA regional offices and the heavy-duty engine manufacturers. Their comments and suggestions were reviewed and incorporated by the workgroup into the recommendations contained in this report.

Primary Recommendations

All of the recommendations detailed below represent the views of the Retrofit/Rebuild workgroup and NESCAUM.

1. Use of Urban Bus Program Certified Technologies

Oxidation catalysts certified with the Urban Bus Program should be eligible without administrative or peer review for use in any highway heavy-duty engine, with states being allowed to claim a 20 percent reduction for PM, a 40 percent reduction for carbon monoxide (CO), and a 50 percent reduction for HC. These credits may be claimed before a project is implemented. Verification of emission reductions should be conducted during or after project implementation by 1) a review of retrofitting records and 2) through in-use emissions testing. These recommendations are detailed in Chapter I, section D and Chapter III.

For use of technologies certified with the Urban Bus Program that are engine specific such as rebuild kits, the workgroup recommends that a PM emission reduction credit of 20 percent be granted automatically when the rebuild kits are used in engines that the technologies are certified for under the Urban Bus Program. Chapter I, section B describes the credit allowed for “.1” technologies. As with the use of oxidation catalysts, reporting and in-use testing recommendations for rebuild kits are detailed in Chapters I.D and III.

2. Use of Technologies Not Certified with the Urban Bus Program

For all products that have not been certified with the Urban Bus Program, emissions testing should be conducted by the manufacturer to determine the emission reductions potential (percent reductions) of the retrofit/rebuild product. Similar data should be required for the voluntary program as are required for certification with the Urban Bus Program (see Chapter III, section A for a detailed description). An engineering analysis should be conducted by the manufacturer to determine which engines the

retrofit/rebuild equipment may be used on. These data and analysis will be reviewed by the third party verifier to establish the emission reduction level and applicability for engine families for the voluntary retrofit program.

3. Third Party Verification System

A third party verification system should be established which consists of an administrator and a peer review committee. The workgroup recommends that Environment Canada be the administrator for this program. The administrator will process all applications to the retrofit/rebuild program, review data for thoroughness, organize the work of the peer review group, make decisions on the level of in-use testing required, and communicate with EPA. The peer review committee should consist of temporary volunteer members from industry, laboratories, and trade organizations (such as the Society of Automotive Engineers) with expertise in heavy-duty engines and retrofit equipment. The committee will make determinations for emission control devices on the level of in-use testing, completion of the in-use testing requirement, acceptability of in-use testing method, emission reduction potential of emission control products, and engine families that control equipment can be used with.

4. In-use Testing Requirement

In order to verify the emission reductions claimed from retrofit projects and to assess control equipment durability a percentage of all emission control products installed as part of a retrofit/rebuild program should be tested in-use. The procedure for establishing the number of units to be tested in the field is outlined in Chapter III and is adapted from EPA's in-use compliance testing requirements for new pleasure craft marine engines. An in-use testing trigger should be established for different types of technologies based on unit sales. A 70% pass rate on tested units will be needed in order for devices to "test out" of the in-use requirement.

5. Calculating SIP Credits

In order to calculate SIP credits from retrofit projects, baseline emission factors for heavy-duty engines to be retrofitted needs to be established. The workgroup recommends that Federal Test Procedure (FTP) certification data for engine families be used as baseline emission rates for retrofitted engines. Emission reduction percentages (as recommended in this document for devices certified with the Urban Bus Program and as established by the third party verifier for devices not certified with the Urban Bus Program) can be applied to these baseline rates. Mass emissions reductions can be calculated for individual fleets using the formulas detailed in Chapter IV and information available to fleet operators such as vehicle mileage, hours in operation, or fuel consumption. In some cases, states may choose to develop baseline emission rates through testing of heavy-duty engines in-use. The states will need to develop a testing plan in coordination with EPA to determine these baseline levels.

6. Retrofit/Rebuild Program Information/Website

The workgroup recommends that if possible all retrofit/rebuild devices certified with the Urban Bus Program and all devices “verified” through third party review be listed on a retrofit/rebuild website which states and others interested in undertaking retrofit projects can easily access. The retrofit website could provide SIP credit calculation formulas, information on emission control products, applicable engines, and EPA certification data for engine families.

7. Model State Retrofit Policies

States have policy and funding options to increase the use of retrofit devices to reduce heavy-duty diesel pollution. Retrofitting heavy-duty vehicles and machines to reduce PM, HC, CO, toxics, and in some cases NO_x, can assist states in reaching air quality standards. Executive orders, contract requirements, and agency policies represent potential methods to increase the use of retrofit devices. Funding from federal sources such as the Congestion Mitigation Air Quality Improvement program (CMAQ), state funding in the form of bond issues and agency budgets, and supplemental environmental monies can provide financial support for retrofit projects. The last section of this report outlines model retrofit policies that have been used in the region, funding sources, and example strategies to increase the use of pollution control equipment.

Introduction

A. Background

There are approximately 4.2 million heavy duty diesel vehicles (both highway and nonroad) operating in the United States. These vehicles and equipment emit millions of tons of fine particulates and ozone-forming pollutants annually. Current inventories estimate that heavy duty diesel emissions comprise 33% of all nitrogen oxides (NO_x) and 80% of all particulates (PM) from mobile sources in the Northeast states.² The contribution from this sector is rising as the nation's diesel fleets continue to grow and as vehicle miles traveled increase. Emissions from these engines contribute to serious air pollution problems experienced in many areas of the country. NO_x causes eutrophication of lakes and streams, acid rain, and is a precursor to ozone which aggravates lung disease. Hydrocarbon (HC) emissions are also ozone precursors and are made up, in part, of toxic substances such as benzene, toluene, and 1,3 butadiene, some of which are known carcinogens. PM emissions are very high from diesel engines and aggravate lung diseases such as asthma, emphysema, and bronchitis. In addition, particulates have been labeled a probable human carcinogen by the EPA. Furthermore, the California Air Resources Board (CARB) has labeled PM a toxic air pollutant.

In the long term, reductions in heavy-duty diesel pollution will be achieved through the implementation of more stringent federal emissions standards for new engines. When implemented, EPA's rule for *Control of Emissions of Air Pollution from Highway Heavy-Duty Engines* will reduce NO_x by 50% in the year 2020. Likewise, EPA's rule for *Control of Emissions of Air Pollution from Nonroad Diesel Engines* to be phased in between 1999 and 2008, will reduce NO_x by 50% and PM by 16% by the year 2020. In the near term, however, much needs to be done to reduce emissions from existing engines if state air quality goals are to be met. Achieving emissions reductions from in-use diesels is needed because older engines pollute at much higher rates than newer ones due to deterioration and less stringent emission standards.

The Urban Bus Retrofit Program begun in 1993 was a first step in addressing the problem of in-use heavy-duty diesel emissions. This initiative was the first to require the retrofit of heavy-duty engines to achieve emissions below the original certification levels for the engines. The program was designed to take advantage of commercially available retrofit/rebuild devices that reduce heavy-duty engine emissions significantly. Examples of these devices are oxidation catalysts, fuel borne catalysts, and new engine components configured for low emissions such as pistons and cam shafts.

While oxidation catalysts have been used by heavy-duty engine manufacturers to meet emission standards as original equipment (1.9 million medium and heavy-duty trucks have been equipped with catalysts in recent years), retrofit of existing engines with the same emission

² "Heavy-Duty Engine Emissions in the Northeast" NESCAUM May, 1997.

control devices have been, until the initiation of the Urban Bus Program, uncommon in this country. As part of that program the emission reduction potential of installing oxidation catalysts and other types of add-on equipment in older engines was demonstrated. Engine dynamometer testing has shown that certified technologies have the potential to reduce particulate emissions by as much as 80%.³ In-use emissions testing conducted at the time of retrofit/rebuild and one year later on the same buses shows that significant PM, CO, and HC reductions are achieved.⁴

B. Project Objective

The purpose of the NESCAUM effort described in this report is to encourage the use of both Urban Bus Program certified retrofit/rebuild kits and non-certified technologies by developing a standardized method for states to calculate SIP credits for retrofit projects. The current lack of a standardized method hinders the use of retrofit technologies in heavy-duty engines. Specifically, a protocol for actual credit calculation is needed, a third party verifier to assume responsibilities similar to EPA's in the federal Urban Bus Program, and lastly, recommendations on technology matches between retrofit equipment and heavy-duty engines are needed. This guideline document attempts to address these gaps and in so doing, encourage the use of retrofit/rebuild equipment to reduce emissions from heavy-duty engines.

C. Project Participants

The NESCAUM retrofit/rebuild workgroup was comprised of members from state and federal regulatory agencies, emission control equipment manufacturers, and testing laboratories. The recommendations in this report reflect a consensus of the workgroup participants arrived at during bi-weekly discussions over a period of eight months. The resulting recommendations reflect the collective experience, opinions, and judgment of the workgroup participants as well as opinions expressed by the Engine Manufacturers Association.

In the next section, recommendations for the use of Urban Bus Program certified technologies are detailed.

³ "Environmental Fact Sheet" U.S. Environmental Protection Agency, Office of Mobile Sources, March, 1997.

⁴ "Urban Driving Cycle Results of Retrofitted Diesel Oxidation Catalysts on Heavy-Duty Vehicles: One Year Later," Kevin F. Brown, Greg R. Rideout, Jeffery E. Turner. SAE 970186, February, 1997 and "Urban Driving Cycle Results of Retrofitted Diesel Oxidation Catalysts on Heavy Duty Vehicles" in SAE 960134, Kevin Brown and Greg Rideout, 1996

I. Use of Federal Urban Bus Program Certified Technologies in Heavy-Duty Engines Not Affected by the Federal Urban Bus Program

Currently, seventeen products are certified with the Urban Bus Program and three others are under review. Table I-1 on page 5 summarizes the certified technologies and the types of engines that can be retrofitted with the devices. The workgroup recommends that for the purposes of voluntary retrofit projects, control technologies certified under the federal Urban Bus Program be divided into two categories: engine specific and non-engine specific. Currently, oxidation catalysts are the only examples of technologies that are not engine specific because they are applicable to broad categories of engines. Engine specific technologies are rebuild kits that are manufactured for a certain engine family. The recommendations for these two categories of control equipment are described below.

A. Recommendations for Use of Oxidation Catalysts Certified with the Urban Bus Program in Heavy-Duty Engines

The workgroup recommends that oxidation catalysts certified with the Urban Bus Program be eligible without administrative or peer review for use in any highway heavy-duty engine, with states being allowed to claim a 20 percent reduction for PM, a 40 percent reduction for CO, and a 50 percent reduction for HC. These credits may be claimed before a project is implemented. The workgroup recommends that states and/or emission control manufacturers verify emissions reductions during or after project implementation in two ways by 1) conducting a review of retrofitting records and 2) in-use emissions testing. Details on these recommendations are found in Chapter I, section D and in Chapter III.

The workgroup recommends that percent reductions be used, as opposed to a gram per mile or gram per brakehorsepower hour reduction since mass emission reductions will vary from engine to engine depending upon “engine out” or baseline emissions. Using the percent reductions will allow for different mass emissions reductions to be calculated for many different engine families. States may calculate mass emissions reductions for retrofitted engines by multiplying the baseline emission rates by the percent reductions. This method is detailed in Chapter IV. This method assumes that oxidation catalysts will achieve a minimum of 20 percent reduction for PM, 40 percent reduction for CO, and 50 percent reduction for HC in all heavy-duty engines. These recommendations for oxidation catalysts certified with the Urban Bus Program are based on emission reduction data that are detailed in the next section.

B. Available Data on Emission Reductions from Oxidation Catalysts

Data on emission reductions attributable to oxidation catalysts are available from several sources. The first are test results that were provided to EPA by emission control manufacturers as part of the Urban Bus Program. These data were gathered from both two and four stroke engines and from worst case engines (highest emitters). Another source of information is data that have been published in Society of Automotive Engineering (SAE) journals. Four SAE papers have been written on emission reductions achieved by the retrofitting of urban buses and trucks with oxidation catalysts. Other sources of information on catalyst function are engine manufacturers and emission control equipment manufacturers (additional data not submitted to Urban Bus Program). Lastly, several projects have been conducted in Europe to assess the effectiveness of oxidation catalysts. Table I-2 on page 6 summarizes the results of the available studies.

Taken together, these studies provide data for 60 heavy-duty diesel two and four stroke engines. The data support the assumption that use of oxidation catalysts in both two and four stroke engines achieve PM reductions ranging from 19 to 50% with an average PM reduction of approximately 33%. The data also supports the assumption that reductions of emissions ranging from 50 - 90% for HC and 45 - 90% for CO can be achieved.

Establishing these percent reductions for Urban Bus certified oxidation catalysts will mean that these technologies will be available for credit generation in voluntary retrofit projects without review by the third party verifier. The exemption of Urban Bus Program certified oxidation catalysts (and possibly other broadly applicable technologies in the future) from initial review by the third party verifier is based upon the testing data summarized in table I-2 and attached to this report showing that a minimum of 19 percent PM, 50 percent CO, and 45 percent HC reductions are achieved when different types of highway heavy duty engines are retrofitted with oxidation catalysts. The percent reductions chosen by the workgroup represent nearly the lowest recorded emissions reductions in all of the available studies and are thus conservative.

Use by the states of the recommended conservative reduction percentages will compensate for possible lower than average emission reductions that could occur when oxidation catalysts are installed in a wide variety of engines. The workgroup does not anticipate that emissions will fall below the recommended percent reductions, a more likely scenario will be that reductions will be greater than estimated. However, the conservative numbers provide a safety factor in case emission reductions are lower in certain engines.

Table I-1
Equipment Certified & Status of Notifications of Intent
to Certify Urban Bus Equipment
March 18, 1999
Air Docket A-93-42

Certifier	Equipment Description	Federal Register Notice: Effective Certification Date
1. Engelhard 1	Exhaust catalyst (CMX) for 2 stroke/cycle	60 FR 28402, 05-31-95
2. Engelhard 2	Exhaust catalyst (CMX) and cermatized engine parts	60 FR 47170, 09-11-95
3. Detroit Diesel Corp. (DDC)	Engine upgrade kit for DDC 6V92TA MUI's	60 FR 51472, 10-02-95
	Life Cycle Cost Evaluation	EPA Ltr, 06-24-96 61 FR 37734, 07-19-96
4. Cummins	Engine upgrade for Cummins L10 4 stroke/cycle	60 FR 64046, 12-13-95
5. Twin Rivers Technologies	Biodiesel, exh cat (CMX) & timing retard: 2 stroke/cycle engines	EPA Ltr, 09-20-96 61 FR 54790, 10-22-96
6. Johnson Matthey 1	Exhaust catalyst (CEM 1) for 2 stroke/cycle	EPA Ltr, 03-28-96 61 FR 16733, 04-17-96
7. DDC 2	Engine upgrade kit for DDC 6V92TZ DDECII's	61 Fr 37738, 07-19-96
8. Engelhard 3	ETX 2002 kit: Exhaust catalyst, ceramitized parts, & engine upgrade parts for DDC 6V92TZ MUI (0.10)	EPA Ltr, 02-38-97 62 FR 12166, 03-14-97
9. Engine Control Systems (ECS)	Exhaust catalyst (OCM) for 2 stroke/cycle	EPA Ltr, 12-02-96 62 FR 746, 01-06-97
10. Johnson Matthey 2	Exhaust catalyst (CEM) & engine mods for DDC 6V92TA MUI (0.10)	EPA Ltr, 09-08-97 62 FR 60079, 11-06-97
11. ECS 2	Exhaust catalyst (OCM) for 4 stroke/cycle	63 FR 4445; 01-29-98
12. Engelhard 4	Exhaust catalyst (CMX) for 1992 – 1993 Cummins L10 EC	EPA Ltr, 02-12-98 63 FR 13660; 03-20-98
13. Nelson Industries	Exhaust catalyst for 2 stroke/cycle	EPA Ltr, 10-14-97, 62 FR 63159; 11-26-97
14. DDC 3	TurboPac, exhaust catalyst (OCM), and engine upgrade for DDC 6V92TA MUI (0.10)	EPA Ltr, 04-06-98 63 FR 26798; 05-14-98
15. Johnson Matthey 3	Exhaust catalyst (CEM) & engine mods for DDC 6V92TA MUI (0.10)	EPA Ltr, 10-21-98 63 FR 66798; 12-03-98
16. Engelhard 5	ETX 2002 kit: Exhaust catalyst, ceramitized parts and engine upgrade parts for DDC 6V92TZ DDEC 2 (0.10)	EPA Ltr, 07-01-98 63 FR 50225; 09-21-98
17. Turbodyne Systems, Inc.	TurboPac & exhaust catalyst (OCM) 6V92TA MUI (0.10)	Under review
18. DDC 4	TurboPac, exh cat (OCM, and engine upgrade for 6V92TA DDEC (0.10)	EPA Ltr, 10-02-98
19. Engelhard 6	ETX Plus Technology for DDEC II engines (.1)	Under review
20. Johnson Matthey	CEM Cat Muffler for 4 s/c engines	Under review

Table I-2
Summary of Available Data for Oxidation Catalyst Use in HDD

Study/Report	Number and Types of Engines	PM Reductions	HC Reductions	CO Reductions
Urban Bus and Engelhard data	19 four stroke and 10 two stroke	38% avg. for two stroke 27% avg. for four stroke	51% avg. for two stroke avg. 64% avg. for four stroke	n/a
SAE 960134 ⁵	5 four stroke and 2 two stroke	32.8% avg. for all vehicles	75.9% avg. for all vehicles	67.1% avg. for all vehicles
SAE 970186 ⁶	5 four stroke and 5 two stroke	24% avg. for all vehicles	50-90% for all vehicles	45-93% for all vehicles
SAE 932982 ⁷	4 four stroke	44-60% avg. for all vehicles	n/a	n/a
SAE 950155 ⁸	two stroke buses	32-41%	60-70%	90%
London Bus ⁹ Report MBK 961165	6 four stroke	45%	86%	92%
Engelhard Report #980342 ¹⁰	1 four stroke	49% avg. for three catalysts	93% avg. for three catalysts	98%
APTA paper ¹¹	two stroke	19-44%	50-90%	45-93%

⁵ Brown, K., Rideout, G. "Urban Driving Cycle Results of Retrofitted Diesel Oxidation Catalysts on Heavy Duty Vehicles," SAE 960134, 1996.

⁶ Brown, K., Rideout, G., and Turner, J. "Urban Driving Cycle Results of Retrofitted Diesel Oxidation Catalysts on Heavy Duty Vehicles: One Year Later," SAE 970186, 1997.

⁷ Clerc, J., Miller, R., McDonald, C., and Schlamadinger, H. "A Diesel Engine/Catalyst System for Pick-up and Medium-Duty Trucks" SAE 932982/1993.

⁸ Voss, Adomaitis, Feldwisch, Borg, Karlsson, and Josefsson, "Performance of Diesel Oxidation Catalysts for European Bus Applications," SAE 950155 1995.

⁹ Millbrook Proving Ground Ltd. "Evaluation of a Reformulated Catalyst Developed by Lubrizol on Exhaust Emissions on London Double Decker Buses." Report No. MBK 961165, January 1997.

¹⁰ Millbrook Proving Ground Ltd. "Evaluation of Catalysts developed by Engelhard on Exhaust Emissions on London Double Decker Buses," Report No. 980342, April 21, 1998.

¹¹ Brown, K., Rideout, G., and Turner, J. "Long Term Emission Evaluation of In-Service Transit Buses at OC TRANSPO. Paper delivered at the 1997 APTA Bus Operations, Technology, and Maintenance Conference.

Oxidation catalysts are the only broadly applicable technology currently certified with the Urban Bus Program. In the future, however, other broadly applicable technologies may become certified with the program. If this is the case, the workgroup recommends that the third party verifier (described in Section II) determine the level of percent reductions for the technology by a careful analysis of emissions testing data.

The above sections describe the available credit that can be claimed by states when heavy-duty highway engines are retrofitted with oxidation catalysts certified with the Urban Bus Program. In the case of retrofit of heavy-duty nonroad engines both land-based (construction equipment, agricultural equipment, gen sets, and locomotive engines) and marine based (ship engines and auxiliary power units) with oxidation catalysts, the review committee may need to establish the percent reductions that can be claimed after an examination of available data. In this case, oxidation catalysts certified with the Urban Bus program will be considered as technologies not certified with the Urban Bus Program (described in Section II).

Technologies certified with the Urban Bus Program will also be considered with those that are not certified with the program in the case of a request from the manufacturer for a greater percent reduction. For example, a manufacturer of an Urban Bus Program certified technology may want to verify a product to a greater emission reduction level than is established in these guidelines. In this case, emission control equipment manufacturers will need to provide additional testing data and/or an engineering analysis to the third party verifier to establish the emission reduction level and applicable engines.

Fine Particulates

While the study of fine particle concentrations in the exhaust of heavy-duty engines equipped with oxidation catalysts is relatively new, three reports are available which have examined the numbers and size of particulates in exhaust from oxidation catalyst equipped heavy-duty engines. The studies compared the numbers and sizes of particles both before and after installation of retrofit equipment. All three studies showed that no increase in the number and no decrease in the size of particulates was found. An excerpt from one of these studies, published by the Health Effects Institute, is appended to this report. Since fine particles are highly respirable and deliver toxins deep into the lung, any decrease in the size of particles emitted from heavy-duty engines increases the risk of aggravated lung disease. The three available studies demonstrate that in an initial examination of this issue, oxidation catalysts do not increase the number or decrease the size of fine particles in diesel exhaust.

C. Engine Specific Technologies Certified with the Urban Bus Program

Technologies certified with the Urban Bus Program which are designed for specific engines are rebuild kits. These kits contain components which reduce emissions from heavy-duty engines. Typical components are pistons and cam shafts. In the Urban Bus Program rebuild kits are certified to one of two levels of emission reduction: 25% and .1 grams per brake horsepower hour (g/bhp-hr). The workgroup recommends that these kits be pre-approved for use with the engines they were certified for under the federal Urban Bus Program without approval from the review committee.

For .1 g/bhp-hr certified kits using engine-specific components, the workgroup recommends that these kits be pre-approved for the engines they are certified for and that the emission reduction credits for PM be calculated as a percentage derived from the engines' certification level and .1. For the technologies which also employ an oxidation catalyst a further credit of 40% CO and 50% HC is recommended by the workgroup. However, if the manufacturer of the technology wishes to verify that the retrofit/rebuild kits can be used in engines other than those specified under the Urban Bus Program, then additional data must be given to the third party verifier supporting the manufacturer's claim, the proposed use of the technology, and the amount of credit to be granted.

For .1 certified technologies that are not engine specific, the review committee should establish the emission reduction potential and the applicable heavy-duty engines. This would be the same review process used to verify all other non-engine specific emission control equipment (other than oxidation catalysts).

For use of rebuild kits certified to the 25% PM emission reduction level, the workgroup recommends that a 20% PM reduction credit be automatically granted for the use of these kits in the engines they are certified for use with under the Urban Bus Program.

D. Accuracy of Expected Emission Reduction Estimates

An important aspect of credit calculation is determining the level of uncertainty in the estimated emissions reductions. While the above referenced studies present data on emissions reductions from a representative sample of two and four stroke engines, some uncertainty exists in extrapolating the existing data on these engines to all heavy duty engines. Two issues related to this are addressed below 1) establishing accurate estimates of retrofit project emission reductions; 2) compensating for variability resulting from program implementation.

First, the goal of establishing accurate estimates of emissions reductions will be furthered by state screening of engines to be retrofitted and the exclusion of those that are not well suited for retrofit equipment. For example, engines with extreme wear (those engines that will soon need to be replaced) are not good candidates for retrofitting. Additionally, manufacturers of

emission control equipment will need to carefully assess the engines which they retrofit. For example, proper sizing of catalyts and use of appropriate pipe sizes will be necessary to ensure that the maximum emission reduction is achieved and backpressure is not increased beyond manufacturer specifications.

Second, variability in the implementation of a retrofit program could result, for example, from greater or lesser participation in the program than anticipated. If a different number of vehicles are equipped with emission control devices than expected this will change the emission reductions achieved by a retrofit project. In order to compensate for such variability, records will need to be kept by fleet operators so that states may verify the numbers of vehicles that have been retrofitted. States may need to revise SIP credit calculations according to the actual number of vehicles retrofitted during the course of a program.

The next sections describe the workgroup recommendations on record keeping, reporting, labeling, and warranty provisions which should be followed by states and emission control equipment manufacturers in order to reduce the uncertainty in calculating emission reductions from retrofit projects.

Reporting Program Results

In order to accurately evaluate retrofit program results, the workgroup recommends that states or others initiating retrofit projects develop a system for monitoring projects. Comparing projected emissions with actual emission reductions achieved can be done by keeping careful record of the numbers of vehicles retrofitted and if possible the miles traveled in fleets of retrofitted vehicles. These records can be used to re-calculate emission reductions mid-way through the project and at the project's end. Reporting requirements are described below.

A state's obligations with respect to voluntary mobile emission reduction programs (VMEPs) must be enforceable at the state and federal levels. Under this policy, the state is not responsible, necessarily, for implementing a program dependent on voluntary projects. This is so since voluntary projects under VMEP can be conducted by private groups. An example of such a project might be the retrofit of construction equipment at the site of a large project which is intended to mitigate emissions from the project. However, if the state is claiming SIP credits from the project then the state is obliged to monitor, assess and report on the implementation of voluntary actions and the emission reductions achieved from the voluntary actions and to remedy in a timely manner emission reduction shortfalls should the voluntary measure not achieve projected emission reductions.

Careful reporting will allow for enforcement of retrofit projects. CFR section 85.1404 outlines the reporting requirements for fleet operators who are retrofitting fleets as part of the Urban Bus Program. These requirements will be adopted for fleet operators retrofitting heavy-duty engines as part of voluntary projects. The requirements state:

The operator of any (vehicle) for which this subpart is applicable shall maintain and retain the following adequately organized ... records. Each operator shall keep such records until the useful life of the oxidation catalysts is achieved.. (1) General records. The records required to be maintained under this paragraph shall consist of all purchase records, receipts, and part number for parts and components used in the rebuilding of (vehicle) engines.

In addition to reporting requirements, a warranty will be made by emission control equipment manufacturers that guarantees emissions reductions for a certain period of time to be set for each oxidation catalyst by the manufacturer. This will also be used in credit calculation.

Warranty of Emission Control Equipment

The same warranty that is required under the Urban Bus Program should be required by retrofit emission control equipment manufacturers for technologies being used as part of this voluntary retrofit program (as detailed in section 85.1409). It reads:

As a condition of certification the retrofit/rebuild equipment certifier shall warrant that if the certified equipment is properly installed and maintained as stated in the written instructions for proper maintenance and use, the equipment will not cause a (vehicle) engine to exceed the emission requirements of this subpart and the emission standards set forth in 40 CFR part 86. This retrofit/rebuild equipment warranty shall extend for (number of miles to be specified). (b) As a condition of certification, the retrofit/rebuild equipment certifier shall provide an emissions defect warranty that if the certified equipment is properly installed and maintained as stated in the written instructions for proper maintenance and use, the equipment certifier will replace all defective parts, free of charge. This emissions defect warranty shall extend for a period of (number of miles to be specified) miles from when the equipment is installed.

The period of credit life shall be no more than the emissions warranty. User voiding of the mechanical warranty voids the emission warranty.

Monitoring vehicles for enforcement purposes will be made possible by labeling all vehicles that have been retrofitted.

Labeling requirements

All retrofit equipment should be affixed with a label that states the model and serial number of the emission control equipment and the name of equipment certifier. The label must be durable and readable for the in-use compliance period of the equipment.

II. Third Party Verification

The workgroup recommends that a group be established to conduct third party verifications. This section describes the third party verification system and the role of the verifier. The responsibilities of the third party verifier include 1) reviewing applications and screening applicants; 2) making determinations on emission reduction potential and which engines the technologies can be used with; and 3) overseeing the in-use testing program.

A. Third Party Verification Structure

The workgroup recommends that the third party verifier be comprised of three groups: 1) an administrative group; 2) a voting review committee; and 3) a non-voting review group. In addition, we recommend that EPA have oversight responsibilities in the program and veto power on any decisions made in the retrofit program. The following sections describe the roles of each of the three groups. The decision making processes in the third party verification system are illustrated in the flowchart on page 13. Arrows indicate how information will be exchanged between EPA, the administrative group, and the review committee. Dotted lines indicate points in the third party review process where information on decisions or testing data is sent to EPA, but no response is needed in order for further decisions to be made.

1. The Administrative Group

The administrative would oversee the retrofit program, interact with applicants and participants, organize the review committees (both voting and non-voting), and communicate with EPA. The workgroup recommends that Environment Canada's Emissions Research and Measurement Division (ERMD) assume the responsibilities of the administrative body. ERMD has agreed to do so and will devote two full time staff members to the retrofit program once it is established. Environment Canada already has an environmental technology verification program which will assist the ERMD in its efforts to set up the retrofit verification system. In addition, ERMD has conducted extensive testing of retrofitted heavy-duty diesel vehicles and has much experience with both heavy-duty engine and emission control technology. This experience provides the Division staff with valuable insights that will be needed in the administration of the voluntary program.

2. The Review Committee

The committee would analyze data submitted to the program administrator and have decision making authority on issues such as the level of in-use testing required (within the guidelines set out in this document) and types of engines that the retrofit/rebuild equipment can be used with. The committee could be comprised of five voluntary, temporary experts in the field of in heavy-duty engines and retrofit technology. Eligible members could be, for example, automotive engineers, laboratory personnel, and retired industry members (but not those currently employed in the emission control equipment industry). The committee should make decisions by a majority vote. At any time, a member of this group may raise an objection about any matter related to the voluntary retrofit program by sending a letter to EPA. EPA may elect to follow up on the objection by investigating the matter further.

3. Non-Voting Review Committee

In addition to the voting review committee, a non-voting review group should be established by the administrator. This group should also consist of volunteers with knowledge of heavy-duty engines and retrofit equipment. State air pollution control program staff and industry members could comprise this group which could be made up of up to ten or twenty people. The group should have access to all of the data which the review committee analyzes. At any time, a member of this group may raise an objection about any matter regarding the voluntary retrofit program by sending a letter to EPA. These objections and/or comments should be made accessible to the public. EPA may elect to follow up on the objection by investigating the matter further.

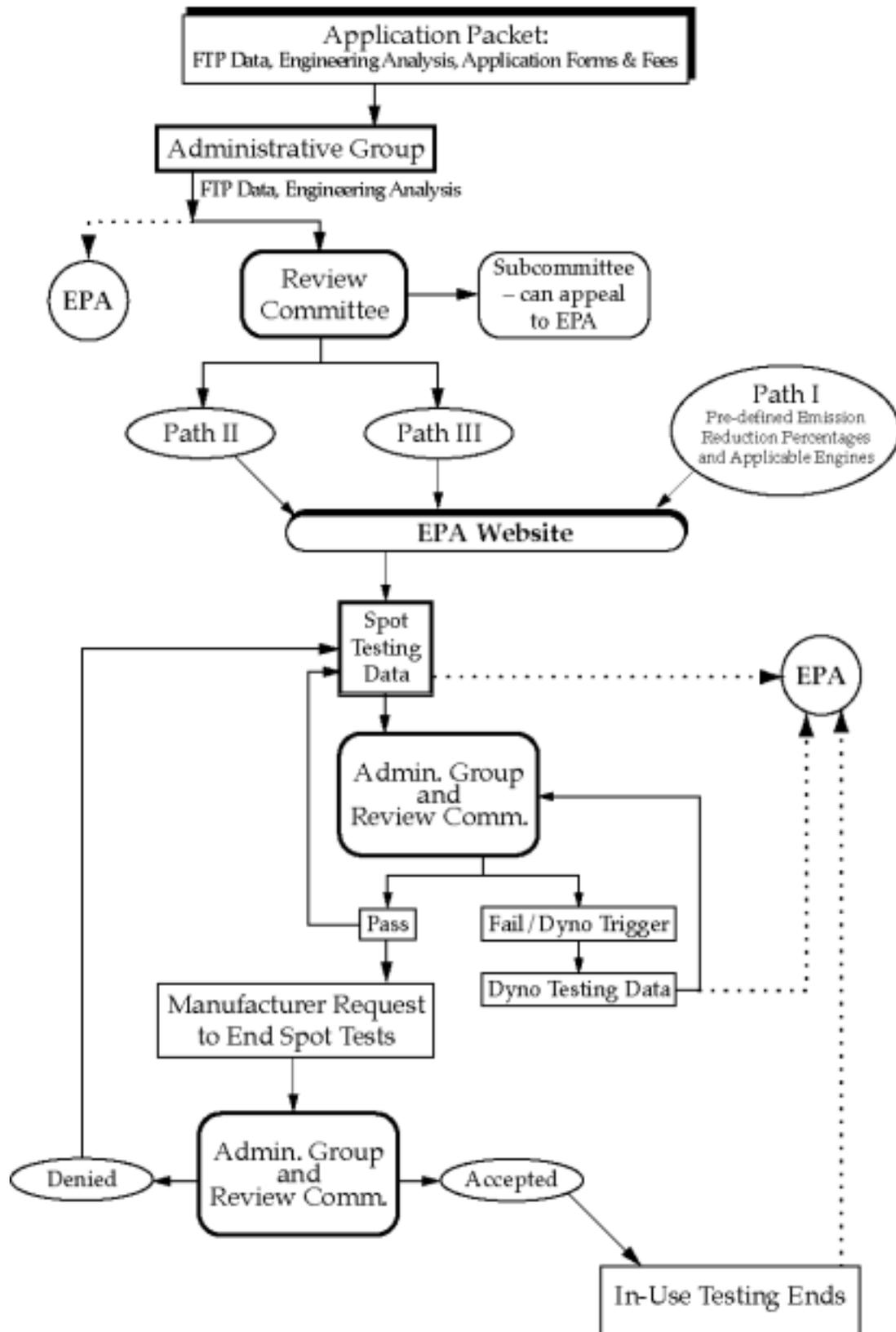
4. EPA Role

The workgroup recommends that EPA provide oversight to the retrofit program. The Agency should have access to all data included in application packages, in-use testing data, and any other data submitted to the administrator. We recommend the following: 1) although EPA would not vote on a regular basis as part of the review committee, it will be a member of the voting group; 2) when EPA votes, its vote should count as six votes, i.e. if EPA decides to become involved on an issue, EPA would have the final decision on that issue; and 3) EPA may occasionally step in where needed, for example, if an audit of a testing lab is deemed necessary.

In addition, the workgroup recommends that any member of the review committee can submit an appeal to the committee and/or EPA at any time regarding any aspect of the approval process. In other words, if a problem becomes apparent on a previously approved product or procedure, there will be an avenue to bring this to public scrutiny.

Last, the final decision to grant SIP credits to states for retrofit projects will rest with the EPA regional authorities.

Retrofit/Rebuild Program Flowchart



B. Role of Third Party Verifier

1. Review of Applications and Screening Applicants (administrative group)

The first step in the application process will be for the applicant to submit a one page summary of the technology and testing procedure to the administrator prior to and/or prior to conducting testing. The summary will be reviewed by the group specifically to determine if special approval needs to be made for alternative testing procedures (see Chapter III, section A for a description of accepted testing procedures). The administrative group will review this summary in a timely manner and give comments to the submitting company.

Second, the administrator will receive and review all applications which will include 1) engine or chassis dynamometer testing data, 2) an engineering analysis which makes recommendations on the engine families the control equipment can be used with, and 3) an application form. The administrator will review the material for completeness and pass the data on to the review committee and to EPA by print or electronic format. The review committee and administrator will attempt to complete their reviews within 60 days.

2. Review Committee Decisions

The review committee will make five different types of decisions for all emission control equipment products: 1) which “path” the control equipment falls into; 2) which engines the control equipment can be used with; 3) what percent reductions can be claimed by states when they use the retrofit equipment in pre-determined engine families; 4) acceptability of the in-use testing method as proposed by the emission control equipment manufacturer; and last 5) a determination as to whether the in-use testing requirement has been fulfilled for the program.

a. Path Determination

The committee will review information on a given product and will designate it as belonging in one of three “paths” or groupings in the retrofit program. The products will be designated as belonging to one of the three paths according to how well established the technology is and the available performance history for the product. The first path is reserved for Urban Bus Program certified products and these products are exempt from an initial review by the committee, except in certain instances as described in the next paragraph. Therefore, some products certified with the Urban Bus Program will not be reviewed by the third party verifier in order to establish percent reductions or the types of engines the products can be used with.

The second path is reserved for technologies not certified with the Urban Bus Program which have an established performance history (such as oxidation catalysts not certified with the Urban Bus Program and fuel borne catalysts registered with EPA). The third path is for technologies which are new and innovative and for which little field experience exists, such as

particulate filters and mobile source selective catalytic reduction. The purpose of placing a technology or product into one of the three paths is to designate different levels of in-use testing. Technologies for which little field experience exists will require in-use testing to begin sooner than for more established technologies to guard against a possible shortfall of credits that could occur if new technologies are less effective in reducing emissions than anticipated.

As mentioned previously, path one technologies will be treated as path two in some instances. For example, if manufacturers of Urban Bus Program certified rebuild kits opt to establish that kits can be used in different engines than they are certified for, testing data and/or an engineering analysis to demonstrate the applicability to the different engines will need to be submitted to the third party verifier. In this case a review of the testing data and the engineering analysis will need to be conducted by the third party verifier before information on the product can be made available to states through the voluntary program. Furthermore, a manufacturer may wish to demonstrate higher emission reduction levels than the different values recommended in this report. For example, if a manufacturer has data showing that an oxidation catalyst certified with the Urban Bus Program can achieve a 30 percent PM reduction in certain engines, that manufacturer may want the product to be listed with the voluntary program at the higher PM reduction level. Again, data to substantiate this will be required as well as a review by the third party verifier. In this case, it may be possible to apply for additional credit retroactively for up to five years.

b. Engineering Analysis Demonstrating Applicability to Engine Families

The retrofit device manufacturer will submit to the administrator an engineering analysis conducted either in-house or by an outside group. The analysis will use sound engineering and judgment to determine what engine families the retrofit/rebuild equipment can be used in. Particulate matter composition soluble organic fraction estimates, exhaust temperature, duty cycle and other operating conditions will be considered in the engineering argument. Relational data may be used with *logical and reasonable* assumptions. The committee will review the engineering analysis to determine which engine families the control equipment can be used with. In reviewing the submission, the review committee will use good engineering and scientific judgment and analyze all submitted data on a given product to make its determination. The review committee will document each decision and submit records to the administrator so that the analysis can be justified if EPA opts to review the committee decision.

c. Percent Reductions

The emission control equipment manufacturer will supply either engine or chassis dynamometer testing data to support emission reduction claims for a given product. The percent reduction levels will be established by calculating the difference between baseline or engine out emissions and post-baseline (or post retrofit) emissions. For example, post-baseline PM

emissions in gr/bhp-hr of .2 would be divided by baseline PM emissions of .3. This figure would then be subtracted from one to arrive at the percent reduction. The committee will review all data generated by the applicant to determine the amount of credit that can be claimed by states or others that retrofit heavy-duty engines with the applicant's product. The data to be generated is specified in Section III.A. The committee will chose conservative percent reductions for PM, CO, HC, and NOx (if applicable) after reviewing all of the submitted data.

d. Overseeing In-use Testing

The committee will review the spot test method proposed by the emission control equipment manufacturer. If it is approved, the manufacturer will use this method in the field to test the emission control equipment (in-use testing described in Section III.B.3). The manufacturer will not be required to have the spot check method developed at the time of the submission of the application materials. Rather, the method must be approved by the time spot testing is triggered. The manufacturer will also propose a method for dynamometer testing should it be triggered.

Once spot testing has been triggered, emission control equipment manufacturers will begin testing units in the field. All of the data from spot testing will be sent to the administrator and to the review committee. The committee will be responsible for making a final decision on whether or not the percent passing rate has been achieved. If the spot testing rate is not achieved the review committee will decide if dynamometer testing should begin. This decision will be made in conjunction with the administrator and the emission control equipment manufacturer. In some cases, further spot testing may be done before dynamometer testing begins.

e. Determination of Compliance with In-use Testing Requirement

The committee will review all of the spot testing (and possibly dynamometer testing) data to determine if the required number of units have been tested in the field and if the necessary passing rate has been achieved. If the data shows that this rate has been achieved then the review committee will notify the emission control equipment manufacturer that the in-use testing requirement has been satisfied for a given product.

f. Test for Additional Credit Beyond that Established as a Minimum

States and emission control equipment manufacturers may want to conduct additional testing to establish greater reductions from retrofit projects than the default values previously recommended. This may occur in two cases. First, emission control manufacturers could conduct testing to establish that control equipment achieves higher than default reductions. For example, oxidation catalysts certified with the Urban Bus Program will receive a 20 percent PM reduction credit automatically. If an emission control equipment manufacturer wants to establish

that a given technology can achieve a greater percent reduction, they will provide additional data to the third party verifier and verified information will be posted on the retrofit website. Testing data will need to be collected either using chassis or engine dynamometer methods.

In a second case, states may want to conduct testing to show that baseline emissions are higher than are assumed in the SIP credit calculation. Since the credit calculation is based upon certification testing data and could be different than emissions in-use, state testing of fleet vehicles could determine a higher mass baseline emission rate. Applying emission reduction percentages to this higher baseline rate will result in a greater mass emissions reduction. Testing to determine higher baseline emissions will need to be conducted in-use.

De-certification

The emission control equipment being used as part of this voluntary program may be de-certified or de-listed as is the case in the Urban Bus Program if: 1) the technology becomes de-certified under the Urban Bus Program (as described in 40 CFR 85.1413); 2) use of the certified equipment is causing engine emissions to exceed emission requirements for any regulated pollutant; 3) use of the certified equipment causes or contributes to an unreasonable risk to public health, welfare or safety or severely degrades drivability operation or function; 4) in-use testing requirements and subsequent dynamometer testing indicates the technology is not performing as approved; or 5) a manufacturer opts out of the program.

III. Testing Requirements

This section describes workgroup recommendations on the testing requirements for both technology verification and in-use testing. In addition, the types of testing data that are recommended for submission to the third party verifier are also detailed. Table III-1 summarizes the requirements and sales volume triggers.

A. Establishing Emission Reduction Potential (verification data)

1. Default Test Procedure for Verification

The testing data requirements for all technology verifications will be equivalent to that which is specified for the federal Urban Bus Retrofit/Rebuild program as described in CFR part 85.1406. As with the federal urban bus retrofit program the accepted test method will be the Federal Test Procedure (FTP). Any applicant submitting data generated using the FTP test will not need prior approval from the review committee of the testing procedure. The applicant will follow the data generation requirements as outlined in part 85.1406.

If it is not appropriate to use the FTP cycle or if a technology developer wants to generate data using a test cycle that is different from the FTP, then the workgroup recommends the use of: 1) test methods recommended by EPA, such as the 8-mode cycle for verification of a technology with nonroad engines; 2) test methods recommended by CARB; 3) the Central Business District cycle (CBD) or the New York Bus Composite Cycle (NYBCC) for chassis dynamometer testing.

2. Possible Alternative Testing Cycles

If a technology developer has already generated data using a cycle that is not included as a default testing method then the cycle will need to be reviewed by the administrative group and the review committee. Such cycles could include, for example, the R49. In such a case the 60 day review period limit will not be valid.

B. In-use testing requirements

Once a pre-determined number of retrofit/rebuild kits have been installed in heavy-duty engines, a sales volume trigger will require emission control equipment manufacturers to begin testing units in the field to ensure they are working properly. Table III-1 describes the volume triggers that apply to different types of retrofit/rebuild equipment. The equipment will first be “spot-checked” using cost effective methods to determine if emission reductions are being

achieved. For example, a potential method for testing CO emissions reductions resulting from oxidation catalysts in-use could be to use an electrochemical portable analyzer with probes inserted both upstream and downstream of the oxidation catalyst. The engine could be loaded using a brake stall test, a rolling acceleration, or by driving the vehicle on a normal operating route. Another potential in-use testing method could be to measure hydrocarbon emissions with a flame ionizer detector (FID).

Other in-use testing methods will need to be devised for technologies such as rebuild kits and fuel borne catalysts. Manufacturers of such types of emission control equipment may need to pick a number of vehicles that are candidates for engine rebuild or additive use (for example) and designate those engines for baseline testing before the retrofit/rebuild and then again after retrofit/rebuild to measure post-baseline emissions. In these cases, issues such as engine drift or the change in baseline emissions that can occur over time will need to be addressed.

Engines to be spot-checked will be determined by (to the extent possible) a random process. The results will be submitted to the review committee. Should EPA determine strong bias in testing, EPA may require corrective action, i.e. additional spot-checks of non-represented engines. A random sample should include a mix of end-user entities as well as mileage/usage accumulations.

1. Spot-Testing Overview

The Workgroup recommends that the in-use testing requirements be modeled after EPA's mandatory requirements for in-use testing of marine pleasure craft engines. For each product (emission control equipment product) once the number of units in the field have reached a certain sales volume trigger (as outlined in Table 2) field testing of the product will begin. After the pre-determined number of units have been put in service, four units must be field tested in-use at a mileage or hours accumulation of over half of the manufacturer's designated useful life. The following sequence would then occur:

- If testing is successful (i.e. all units pass) then in-use testing ceases;
- If testing is unsuccessful and the cause can be attributed to the product and not to maintenance or other engine related problems, then for each failed unit, two or more units would be evaluated up to a maximum of ten. If the failure is engine or maintenance related, then the manufacturer could re-test on another vehicle.

For example,

- 1) if one of four units fails, two more units must be evaluated. If both of these units pass, then testing would be considered successful (>70% success rate) and in-use testing ceases;
- 2) if both of these units fail, four more units would have to be field tested and all four units would have to pass in order to meet the 70 percent requirement for in-use testing to cease. If any of the units fail, then the review committee would recommend dynamometer testing because the 70 percent success rate had not been achieved and a total of ten units have been tested which is the maximum limit (according to the marine rule). The manufacturer may have the option to request to extend the in-use testing program in order to achieve a 70 percent success rate in lieu of dynamometer testing. The review committee would be left to determine at what point during the extension, dynamometer testing should be performed. If the manufacturer demonstrates a 70 percent success rate during the extension, in-use testing would cease.
- 3) If one of the two additional units fail (<70 percent success rate), two more units would be tested.
- 4) If both of these units pass (>70 percent success rate), testing is considered successful and in-use testing ceases.
- 5) If both fail (<70 percent success rate), dynamometer testing would be recommended because a 70 percent success rate could not be achieved with in-use testing limited to ten units. Again, the manufacturer would have the option to request an extension to the in-use testing program.

The above is just one example. Consider the case where two of the initial four units failed. This would mean that all ten units would have to be evaluated in order to achieve the seventy percent criteria and only one additional failure would be allowed. In the event that three of the initial units failed, the seventy percent criteria could only be achieved by testing all ten units with no additional failures. If all four failed, the seventy percent criteria could not be achieved and dynamometer testing would be recommended with the option for the manufacturer to request an extension.

In the event of a failure on dynamometer testing, EPA would automatically be notified.

2. Dynamometer Testing

In addition to a “spot check” method such as using an electrochemical portable analyzer, a more comprehensive testing method needs to be developed by the product manufacturer in the case of dynamometer testing. For example if an oxidation catalyst fails spot tests and must then be tested in dynamometer tests, then a potential testing method would be to remove the catalyst and attach it to a “slave” engine in a testing lab. Another possibility could be to test on a mobile chassis dynamometer. As in the case of verification testing, the third party verifier will automatically approve of a method that uses either the FTP or other EPA approved test cycles, CARB approved test cycles, the CBD, and the NYBC cycles. Alternative cycles may be used, but must first be approved of by the review committee. A pass rate of 66.7% must be established or credit will be revoked. The manufacturer may conduct as many tests as are necessary to achieve this percent pass rate.

3. Backpressure Measurement

In addition to emissions testing, backpressure measurements will be taken during field testing to ensure that retrofit equipment is not increasing backpressure beyond manufacturer specifications in retrofitted engines.

Table III-1
Detail of Requirements for Retrofit Technologies

PATH	I	II	III
Path Description	Urban Bus certified retrofit/rebuild kits Technologies certified with the Urban Bus Program in the future will be included.	Technology is in widespread use; demonstrated in-use durability experience; good knowledge of emission reduction mechanism/reduction potentials	New technology, little experience or use. Little in-use/durability experience. Little knowledge of emission reduction mechanism/reduction potentials
Example Technologies	Current Urban Bus certified technologies	Non-urban bus certified catalysts, registered fuel borne catalysts	Selective catalytic reduction
Pre-Credit Requirements			
Certification	Urban Bus certified product, Requirements already completed	FTP dynamometer testing by a recognized lab, or other pertinent data; applicability analysis, durability analysis	FTP dynamometer testing by a recognized lab, applicability analysis, durability analysis
Engine Family	Use of oxidation catalysts automatically approved for all heavy-duty engines; for engine specific technologies only specified engines are approved; all others must be supported by engineering analysis and approved by review committee.	Engine family recommendation by review committee	Engine family recommendation by review committee
Spot Check	Develop accepted spot-check procedure before 500 units are in the field	Develop accepted spot-check procedure	Develop accepted spot-check procedure
Information Posted on Retrofit Website			

Table III-1 (continued)
Detail of Requirements for Retrofit Technologies

PATH	I		II		III	
Post-Credit Requirements						
Number of Units in Use by Manufacturer	In-use Verification Requirements	In-use Testing Requirements	In-use Verification Requirements	In-use Testing Requirements	In-use Verification Requirements	In-use Testing Requirements
Less than 100 Units						spot testing begins
101-1,000 Units				spot testing begins	Performance review by review committee	
1001+ Units	Performance review by review committee	spot testing begins	Performance review by review committee		Confirmation of performance review by review committee, results submitted to EPA	
10,000 plus units	Confirmation of performance review by review committee, results submitted to EPA		Confirmation of performance review by review committee, results submitted to EPA			

IV. Protocol for Calculating SIP Credits

In this chapter, methods for calculating SIP credits from retrofit projects are described. The SIP credit calculations requires that baseline emission rates be established and emission control equipment reductions be applied to those baseline rates. In addition to baseline emission factors and percent reduction levels other information will be necessary in order for states to complete the SIP credit calculations. Details of this information and where it can be obtained are described in this chapter. The chapter has four sections:

- 1) Section A describes a retrofit website to assist states in SIP credit calculations;
- 2) Section B provides an overview of the SIP credit calculation procedure;
- 3) Section C proposes baseline and post-baseline emission factors;
- 4) Section D identifies three formulas for SIP credit calculation;

A. Retrofit Program Information/Website

The workgroup recommends that a retrofit website be developed which will provide much of the information needed to complete SIP credit calculations from retrofit projects. It is recommended that EPA maintain this website and develop links to EPA databases containing heavy-duty engine emissions factors, brake specific fuel consumption, and other information needed for the calculation of SIP credits resulting from heavy-duty retrofit projects. All of the information to be included on the website is detailed below.

Retrofit products verified through the voluntary program

The website should include a list of the products certified with the Urban Bus Program and all of those "verified" by the third party system proposed in this report. For each product listed on the website, the manufacturer name and contact information should be included. For products which are verified by Environment Canada and the review committee, as proposed in this report, information on retrofit/rebuild products should be posted on the website after the review committee has completed its analysis and approval of the manufacturer's application. The site will need to be updated periodically to include newly verified products. In addition to products which are approved by the Urban Bus Program and by the proposed third party verification system another avenue for inclusion in the program may be possible in the future. Currently,

several technology verification programs exist that are organized by states, such as the Massachusetts "STEP" program, or by professional organizations such as the Civil Engineering Research Foundation. In the future, the proposed third party verifier may sign reciprocity agreements with other certification/verification programs. If this is the case, all of the products made available through the reciprocity agreement/s should be posted on the retrofit website. Specifically, the product name, manufacturer, contact person and telephone number, and technology type should be listed.

A list of engines which can be retrofitted with verified products

In addition to information on verified retrofit products, engine models which the emission control equipment may be used with will be posted on the website. As mentioned in previous sections, these engine families will be determined through an engineering analysis conducted either by the emission control equipment manufacturer or by a contractor hired by the manufacturer. The analysis will be reviewed by the third party verifier and, if approved, information on the engines which can be retrofitted with a given product will be posted on the retrofit website. In some cases, this information may simply indicate that a product is available for use with any highway heavy-duty engine. For example, oxidation catalysts currently certified with the Urban Bus Program would be in this category of control equipment. Other products may be listed for use with a few specific engine models. This would be the case with rebuild kits which are manufactured for certain engines.

Percent reductions for each product

As with applicable engines, approved emission reduction percentages for each product will be included in the website. As mentioned previously, data supporting the percent reductions will be gathered during engine dynamometer or chassis dynamometer testing and be presented to the third party verifier. Once the reductions are approved by the third party verifier they will be posted on the retrofit website. For instance, if a product is verified to reduce PM by 20 percent in all heavy-duty highway engines then the 20 percent reduction figure should be listed next to the product and applicable engines. In some cases, a product may be verified to reduce PM by 20 percent (for example) in one engine family and 27 percent in another engine family. If so, then the website will indicate the different levels of reductions that can be achieved in the various engines. While the above example mentions PM emissions, the same level of detail for percent reductions will be provided for all pollutants.

To the extent possible, each product should have the percent reductions listed in a way that makes it easy for the website user to compare different reductions for various

products. In this way the user can choose the equipment which will result in the highest pollution reduction for the fleet to be retrofitted.

The information for engine families, applicable retrofit products, and percent reductions may be organized in a table similar to the one found on the next page. The table provides an idea as to the types of information that will be posted on the website but does not necessarily represent the most efficient method of presenting the information. For example, it may prove easier to use the table if the data is organized by engine family rather than retrofit product.

Other information

In order to complete SIP credit calculations, states will need to have access in some cases to fuel sulfur adjustment factors, factors to convert between gr/bhp-hr to grams per mile, fuel density, a conversion factor for grams to tons, and average load factors. The purpose of these data will be described in Section D.

Sample Retrofit Website Product and Engine Information Table

Manufacturer	Product/ Technology	Engine Applications ¹²	PM percent reduction	CO percent reduction	NOx percent reduction	HC percent reduction
Cummins	Rebuild kit	Cummins L-10	20%	n/a	N/a	n/a
Detroit Diesel	Rebuild kit	DD 6V92 TA MUI	20%	n/a	N/a	n/a
Engine Control Systems	OCM catalytic converter	all heavy duty diesel engines.	25%	40%	N/a	50%
Engelhard	CMX -5 catalytic converter	same as above	25%	40%	N/a	50%
Johnson & Matthey	CEM catalytic converter	same as above	25%	40%	N/a	50%
Nelson Industries	exhaust catalyst	same as above	25%	40%	N/a	50%

¹² In this table engine *models* are listed. Conversely, on the retrofit website engine *families* will be listed.

Website Design

In the following sections, methods for calculating mass emission reductions from retrofit projects are described. Ideally, once the retrofit website is established, states will be able to calculate these reductions on the site by using interactive forms. The purpose of developing the interactive pages of the website is to create a “user friendly” system that states will be able to use to estimate emission reductions from retrofit projects. An interactive format would provide menus of options, list the order in which information should be input, and allow for the inclusion of data found in EPA databases. The interactive site will allow the user to calculate SIP credits on the website forms.

Several features will need to be developed for the website in order to create this “user friendly” system. First, the workgroup recommends that EPA link databases containing certification data on pollutant levels for engine families. If this is done, the website user will not need to research baseline emission rates but rather will have the information readily available. Once the baseline emission rates are established for individual engine families in a fleet the percent reductions for retrofit products (found in another table in the retrofit website) will then be applied to the baseline emission rates. Other information needed to complete calculations such as fuel sulfur adjustment factors should be automatically linked to engines certified in years prior to the introduction of low sulfur diesel. Average load factors and tables of conversion factors should be made available to the user through menus of options. A means for easily incorporating data selected in linked files should be developed. For example, double clicking on the data could automatically incorporate it into credit calculations.

In the next sections the calculation procedure to be used to calculate SIP credits is presented. Section B provides an overview of the protocol and Section C details the specific formulas and their explanations.

B. SIP Credit Calculation Procedure

The general procedure for calculating SIP credits from retrofit projects will be as follows:

- 1) Establish baseline emission factors for PM, HC, CO, and NO_x (if applicable) for each engine family in a fleet to be retrofitted;
- 2) Multiply the emission reduction percentages (as recommended in this document or as established by the third party verifier) for the control equipment that will be retrofitted onto fleet heavy-duty diesel engines to the baseline emission levels for those engines;
- 3) Convert the mass emission reduction level from gr/bhp-hr to one that can be applied to hours of operation, fuel consumption, or miles traveled;

- 4) Multiply the mass emission reduction level by the usage factor (miles to be traveled, remaining usage hours, or fuel to be consumed) to obtain total emission reductions for the engine families;
- 5) Multiply this figure by the fraction of usage that will occur within the state;
- 6) Repeat this process for all pollutants and all engine families in the fleet;
- 7) Add the mass emission reductions for different engine families together for each pollutant to arrive at total mass emissions reductions for the retrofit project.

In the following sections the information and the formulas needed to calculate the SIP credits are detailed.

C. Baseline and Post Baseline Emission Rates

The first step in calculating SIP credits from retrofit projects will be establishing baseline emission levels for engines that will be retrofitted. Since in-use data for a wide variety of engines is not available, the workgroup recommends that data for heavy-duty engine families generated during Federal Test Procedure (FTP) certification tests be used as default baseline emission levels for retrofitted heavy-duty engines. Use of this data will provide emission factors for specific engine families. The data will not account for emissions deterioration that may occur over time and thus the baseline emissions levels will be conservative.

The workgroup recommendation is based on the assumption that establishing emissions for engines through in-use testing is too expensive to be practical. States may opt, however, to conduct emissions testing to establish baseline emissions rates for retrofitted heavy-duty engines. In this case, the emission reduction credits that are generated from a retrofit project are likely to be greater than if the default baseline levels are used due to the fact that in-use testing will account for emissions deterioration which occurs from variable maintenance practices and engine wear. The number of engines to be tested in order to establish the baseline levels will need to be determined by states in coordination with EPA regional offices.

In some cases it may be appropriate for states or fleet operators to use baseline emission factors that are available from in-use testing. For example, if emission factors are available on a gram per gallon of fuel or gram per mile basis for engines that will be included in a retrofit project then these emission factors could be used. These emission factors may be available from in-use testing projects conducted by states, regional organizations, federal agencies, or testing laboratories. For example, the federal Department of Transportation, state environmental protection agencies, and Environment Canada have conducted extensive emissions testing of urban buses. These data could be used for baseline emission rates in lieu of the data gathered during FTP certification for the engines. For example, a municipality not required under the Urban Bus Program to retrofit its urban bus fleet could retrofit its city buses and use existing in-use baseline emissions levels. An advantage of using data gathered during chassis dynamometer testing, as is the case with much of the available urban bus emissions data, is that it is expressed in grams per mile units. These units allow for a more simplified calculation of emission

reductions than does the use of certification data. This is because certification data needs to be converted from gr/bhp-hr to gr/mi.

Other testing programs for marine engines, construction equipment, and heavy-duty trucks could provide emission factors in grams per mile, grams per gallon of fuel, or grams per hour which in some cases could be used for baseline emission factors. States should coordinate with their regional EPA offices on the use of emissions factors developed through in-use testing.

In order to establish mass emission reductions from retrofit projects, the workgroup recommends that baseline emission factors be multiplied by the percent reductions established for each retrofit/rebuild product. These percent reductions must first be established through emissions testing by an established laboratory and be approved by the third party verifier. The multiplication of baseline emission rates by reduction percentages for each pollutant will yield a mass reduction amount for each pollutant. For example, if a product is verified to reduce PM by 25 percent in a given engine and the baseline emission rate is .3 gr/bhp-hr, then the mass emission reduction level will be $.3 * .25 = .08$ gr/bhp-hr. This calculation is detailed in Section D.

The next two sections discuss several methods for SIP credit calculation and present the formulas needed to estimate mass emission reductions from retrofit/rebuild projects.

D. Methods for SIP Credit Calculation

The workgroup recommends that states use one of three methods to calculate SIP credits that result from retrofit projects. The method used will depend on the type of equipment retrofitted and the information available to the operator. The recommended method is to use fuel consumption to calculate SIP credits. If fuel consumption data is not readily available then hours of operation should be the second method used. Lastly, vehicle mileage can be used to determine SIP credits. Providing the three possible methods for SIP credit calculation will allow for the retrofitting of a variety of vehicles. For example, nonroad equipment often do not have odometers, therefore fuel consumption and hours of use are the only methods to determine emission reductions. Additionally, these two methods provide a more accurate estimate of emission reductions than does the calculation involving mileage due to the difficulty in converting from gr/brhp-hr to grams per mile. The three formulas for these calculations are detailed in the next section.

E. Credit Calculation Formulas

This section details the credit calculation formulas that may be used to determine emission reduction credits achieved from retrofit projects. The first formula calculates emissions reductions using mileage data.

1. Formula for calculating SIP credits using mileage data:

This formula requires a conversion from gr/bhp-hr to gr/mi. Information to be provided by the fleet operator includes the number of vehicles to be retrofitted, the fuel consumption for the vehicles, the model make and year of the engines, the fraction of miles traveled within the state, remaining mileage in the fleet vehicles, and the fuel economy of the vehicles. Information linked to the retrofit website will include baseline emissions data, brake specific fuel consumption, fuel density, and the fuel sulfur factor for older engines.

$$\text{MERC}_{\text{pollutant}} = (\text{CL} - \text{FSAF}) * \% \text{ Reduction} * \text{CF}_{\text{bhp-hr/mile}} * \text{N}_{\text{vehicles}} * \text{FM} * \text{FMWD} * \text{CF}_{\text{units}}$$

The different components of the equation are described below:

CL = The original EPA new engine certification level (g/bhp-hr) of the engine family.

FSAF = The fuel sulfur adjustment factor (in g/bhp-hr). For some older engine families certified with high sulfur fuel, this is the amount CL has already been reduced due to the use of low sulfur fuel. For all pollutants except PM, FSAF = 0.

Percent reduction =

This figure is the effectiveness of the retrofit equipment. For example, the percent reductions will be 20% for particulates, 50% for hydrocarbons, and 40% for carbon monoxide for oxidation catalysts. This value represents the effectiveness of the retrofit equipment and is always expressed as a fractional reduction.

CF_{bhp-hr/mile} =

This is the factor to use when converting from g/bhp-hr to g/mile. (Below a description of the calculation is provided).

N_{vehicles} = The number of vehicles with the same emissions certification numbers.

FM =

The remaining average vehicle(s) mileage. This value represents the average expected vehicle life remaining until the fleet is retired or overhauled, whichever occurs first. The value should be determined from historical fleet records of similar vehicles in similar operations with

similar histories. For example, if at the time the retrofit equipment is installed, a municipal agency's records indicate that it operates 12 year old sanitation trucks and that historically their sanitation trucks operate for 17 years then the remaining fleet mileage will be 5 years times the number of miles traveled per year times the number of vehicles to be retrofitted in the fleet.

FMWD = The fraction of mileage within the requesting district. This value is always between 0 and 1.

CFunits = $1.1 * 10^{-6}$ tons/gram or .0000011 tons/gram. The appropriate conversion factor that converts the calculated reductions from grams into tons.

Description of Conversion Calculations

Two additional calculations will need to be conducted in order to complete the above formula. The first calculation adjusts for differing fuel sulfur levels used during engine certification. The second formula is applicable only to the conversion of gr/bhp-hr to gr/mi when mileage data is being used to calculate mass emission reductions.

Fuel Sulfur Adjustment

Engines originally certified prior to the 1994 model year may have been certified with fuel which contains a higher sulfur content than currently available fuels. A heavy-duty diesel engine currently being fueled with a lower sulfur fuel than the fuel with which it was originally certified, may already be emitting significantly less PM than the original certification level documented. In this case, the baseline PM emission level needs to be adjusted according to the fuel sulfur adjustment factor. For HC, CO, or NO_x the FSAF always equals zero because these pollutants are not affected by the fuel sulfur level. PM emissions, however, are affected by fuel sulfur levels and the adjustment is calculated as follows:

$$\text{FSAF} = \text{BSFCb/bhp-hr} * .0917 * (\text{FSFcert} - \text{FSF in-use})$$

where:

BSFCg/ bhp-hr = The brake specific fuel consumption of the engine family in units of g/bhp-hr.

FSFcert = The fuel sulfur fraction of the fuel used to certify the engine family. Typical value = .002(.2%)

FSFin-use = The fuel sulfur fraction of the fuel currently used with the fleet. Typical value = .0005 (.05%).

Conversion calculation from gr/bhp-hr to gr/mi (CF bhp-hr/mile)

When the formula for calculating mass emission reductions using mileage data is used, a conversion from gr/bhp-hr to gr/mi is needed. This conversion is described below.

$$\text{CF bhp-hr/mi} = \text{fuel density/brake specific fuel consumption} * (\text{fuel economy} * (\text{mi/gallon}))$$

These equations need to be calculated for each different engine family that comprise a fleet. For example if there are three types of engine families in one fleet the calculation will need to be done three times. In addition, the calculation must be done for each pollutant. The resulting reductions (for all engine families in a fleet) are added together to obtain the total amount of pollutant reductions that can be included as credit in a state SIP.

2. Formula for calculating emission reduction credits using fuel consumption

The formula that follows is similar to the one described above for calculating emissions reductions using mileage data. Many of the terms in the following formula are the same as in the mileage calculation formula. Readers should refer to the description of the terms above for clarification. The formula for calculating credits using fuel consumption utilizes gallons of fuel consumed for fleet vehicles. Fleet operators will need to know: the number of gallons of fuel consumed by fleet vehicles (on a per engine family or model basis) per year; the number of years the vehicles will be in operation; the number of gallons consumed within state; the model year and make of engines; and the number of vehicles to be retrofitted. Information to be provided on the retrofit website will include: baseline emissions factors in gr/bhp-hr; brake specific fuel consumption; fuel density; and the fuel sulfur factor for older model years. The different elements of the formula are described in the previous section with the exception of variables that are described below.

$$\text{MERC}_{\text{pollutant}} = (\text{CL} - \text{FSAF}) * \% \text{ Reduction} / \text{BSFCg/ bhp-hr} * \text{FD} * \text{Nvehicles} * \text{FG} * \text{FGWD} * \text{CFunits}$$

Where FD is the fuel density and FG is the number of gallons expected to be consumed during the vehicle life, and FGWD is the percent of gallons to be consumed in the state.

Fleet operators who use gallons of fuel consumed during the remaining useful life of the vehicle to estimate emission reductions will not need to calculate the conversion from gr/bhp-hr to gr/mi. This will greatly simplify the emission reduction credit calculation formula. In addition, the uncertainty involved in converting to gr/mi will be eliminated, thus the above formula provides a more accurate estimate of emission reductions than does using fleet mileage data. For these reasons, the above formula is recommended for use in calculating emissions reductions from retrofit projects. The exception to the above statements would occur if states used emission factors (in gr/mi) developed during in-use chassis dynamometer testing. Using these emission factors would allow for a simplified credit calculation using mileage data and would also avoid the uncertainty involved in converting gr/bhp-hr to gr/mi.

The next formula requires that hours of operation be used to calculate emission reductions from retrofit projects. Like the formula described above which uses fuel consumption to calculate emission reductions, the formula described below avoids the conversion from gr/bhp-hr to gr/mi. In addition, this formula is well suited to nonroad machines and equipment which often do not have odometers.

3. Calculating SIP Credits using Hours of Use

The following formula can be used to calculate mass emissions reductions from hours of operation data for fleet vehicles. The fleet operator will need to provide the following information: number of vehicles to be retrofitted, hours of useful life left for each vehicle, model year and make of engines, fraction of hours driven in-state. The retrofit website will provide information on baseline emissions factors; average load factors; fuel density; and the fuel sulfur adjustment factor for older model years.

$$\text{MERC}_{\text{pollutant}} = (\text{CL} - \text{FSAF}) * \% \text{ Reduction} * \text{ALF} * \text{Nvehicles} * \text{H} * \text{HWD} * \text{CFunits}$$

In this equation ALF is the average load factor, H is the number of hours left to be traveled by the fleet and HWD is the percent of those miles to be traveled in the state.

Summary

This chapter detailed three methods and three formulas for calculating mass emission reductions that result from retrofit projects. Each of the formulas assumed that FTP

certification data gathered in emissions testing of new engines would be used for baseline emission factors. As mentioned in the chapter, other baseline emission factors could be used that have been generated during in-use chassis dynamometer testing. If in-use data are used by states for baseline emission factors, the above detailed formulas would not be appropriate for the calculation of mass emission reduction levels that result from retrofit projects. States should coordinate on the development of appropriate credit calculation formulas with their regional EPA offices if in-use baseline emission factors are used.

In the next chapter, state policies to encourage and require the use of retrofit equipment in highway and nonroad heavy-duty diesels are described.

V. Model State Retrofit Policies

Chapter IV outlined how states could establish SIP credits for heavy-duty retrofit projects. This chapter details ways in which states can develop and fund retrofit projects to reduce heavy-duty engine emissions. It does not cover options for retrofitting federally owned heavy-duty vehicles. Heavy-duty engines used in highway and nonroad applications are extremely durable and new emission standards for engines are phased in over a relatively long period.¹³ Given that diesel engines last up to 25 years in some cases, older, higher emitting heavy-duty engines will be in service for the foreseeable future. Since pollutants from these engines contribute to a host of air quality problems, state regulators are exploring near-term options for reducing emissions from this sector. One of the most promising strategies is the use of retrofit kits to upgrade the emissions control capabilities of older heavy-duty engines. This chapter discusses a broad range of regulatory and market-based strategies to promote and encourage the retrofit of heavy-duty engines.

The chapter is divided into three sections. Section A focuses on retrofit strategies for highway vehicles, including mandatory and incentive programs for both public and private vehicles. Section B describes retrofit strategies for nonroad vehicles. Because states are preempted by the federal government from mandating the retrofit of nonroad engines, this section focuses on fee mechanisms and other market-based strategies that can be used to encourage retrofits. In sections A and B, three specific retrofit strategy examples are used to augment the discussion by providing programmatic and technical details for retrofit of different types of heavy-duty engines. Section C describes federal and state funding opportunities for retrofit initiatives. The section also describes federal incentive programs (Voluntary Mobile Source Emission Reduction Program and the Economic Incentives Program) allowing states to claim SIP credits from retrofit projects.

A. Highway Vehicle Retrofit Programs

Heavy-duty trucks and buses are well suited for retrofit initiatives. This is the case because: 1) highway heavy-duty trucks and buses must register with the state, and thus the size and composition of this fleet is better known than that for the nonroad sector; 2) these vehicles are predominantly fleet-based which lends to economies of scale for retrofit projects; and 3) state

¹³ New highway engine emission standards for NO_x will be introduced in 2002 or 2004, and the PM standard as proposed, will remain at the current level (.1 g/bhp-hr) until 2007. For nonroad engines, phase in began in 1996 and will continue through 2008. Appendix B provides a table on phase-in of standards for nonroad engines.

and local governments own or contract with a relatively large number of vehicles and therefore are positioned to affect successful programs.

A variety of factors need to be considered in developing effective retrofit strategies for highway vehicles, including: fleet mileage, the number of vehicles participating in a retrofit project, the duty cycle of these vehicles, current emission levels, and contractual arrangements between state agencies and the fleet. Understanding these elements will help to determine the type and quantity of pollutants to be reduced, the type of retrofit equipment to be used, and the policy options to use for initiating a retrofit project. While mandatory retrofit programs for highway heavy-duty vehicles are possible, programs targeting public fleets and/or voluntary programs may be more viable in the near-term. Moreover, the experience gained through implementing public fleet retrofit projects will provide regulators with information about the appropriate application of these technologies with regard to private fleets. Sub-section 1 describes several policy options for encouraging or requiring the retrofit of state and local fleet vehicles. A specific strategy analyzing technology and policy options for school buses is included as an example of how to evaluate and structure an effective program for retrofitting government owned or contracted fleets. Sub-section 2 discusses retrofit strategies and mandatory programs for privately owned heavy-duty highway vehicles.

1. State Programs to Retrofit Publicly Owned Vehicles

Of the fleet vehicles on the road in the U.S. today, 25 percent are government owned or operated.¹⁴ The percent is considerably larger if all of the vehicles that operate under government contract for student transport, construction, waste hauling, and other purposes are included. Consequently, state and municipal owned/operated vehicles provide important opportunities for emission reducing retrofit projects. In this section, a number of policy options are presented for decision makers to consider when initiating retrofit of state owned vehicles. This list is not exhaustive but provides a starting point with which to consider initiating a retrofit project. States have several options which fall generally into the following two categories: 1) adopting agency policies on the retrofit of state fleet vehicles; and 2) passing laws or issuing executive orders requiring retrofit of state fleet vehicles.

State agencies such as transportation, highway and sanitation departments have the authority to retrofit all or some of the vehicles that they own. Many current retrofit projects have been initiated by states and/or state agencies as a means to reduce emissions from diesels in public fleets. Several mechanisms for both voluntary and mandatory introduction of retrofit projects are discussed below.

¹⁴ Commercial Carrier Journal, August, 1996

a. Transit Authorities

Transit buses, while relatively small in total numbers, represent an important target fleet since these vehicles operate in the most heavily populated areas. Under EPA's Urban Bus Retrofit Program, transit buses that operate in consolidated metropolitan statistical areas (CMSAs) with populations of 750,000 or more are required to be retrofitted with advanced emission control devices at the time of engine rebuild. Transit buses operating in CMSAs with populations less than 750,000 are not covered by the federal urban bus retrofit requirements.

Transit authorities could retrofit urban buses not covered by the federal urban bus program with technologies certified under this program to reduce diesel bus emissions. For example, those cities that have populations less than 750,000 could opt to retrofit their urban buses. Another approach would be to retrofit buses with technologies that achieve even greater reductions than those certified with the Urban Bus Program. The New York Transit Authority provides an example of such an effort in its program to retrofit fifty urban buses in Manhattan with continuously regenerating particulate traps. The traps will reduce PM, HC, and CO pollution up to 90 percent. The use of very low sulfur diesel is a key component of the project. Project participants include the trap manufacturer, fuel suppliers, and the New York City Transit Authority. Funding for the project is provided in part by the New York State Environmental Bond Act discussed later in this chapter.

While the New York program does not involve the adoption of a specific retrofit policy on the part of the Transit Authority, such a policy could be adopted. Precedents for this type of policy exist in alternative fuel programs. For example, the New York City Department of Transportation (DOT) provides a model in its policy to replace all of its 1,100 diesel powered urban buses with CNG vehicles. Transit authorities could adopt similar policies on the retrofit or rebuild of in-use heavy-duty diesels to low emission configurations.

b. Transportation, Sanitation, Highway, and Parks Departments

Transportation, highway, sanitation, and parks departments operate significant numbers of heavy-duty trucks. These trucks are used to collect garbage, operate on public works projects, and maintain public parks. These heavy-duty vehicles would be good candidates for retrofit since the states and local governments have access to the vehicles and generally maintain them at state or local facilities. Retrofitting could take place at the time of regularly scheduled maintenance by mechanics on site. In addition, funding for the retrofits could come directly from the departments that are initiating the retrofit projects or the departments/agencies could apply for federal grants or state funds (see section C).

c. Airport, Port, and Bridge and Tunnel Authorities

Authorities often operate heavy-duty vehicles which maintain roads, airport runways, bridges, and other public facilities. These authorities could opt to retrofit all publicly owned heavy-duty vehicles operating at the facilities. An example of such a program is the Manchester Airport retrofit project. Manchester airport in New Hampshire is undergoing a major expansion funded by an airport bond issue. As part of the expansion, all sixty of the airport's diesel vehicles will be retrofitted with oxidation catalysts certified with the federal Urban Bus Retrofit/Rebuild Program. Equipment to be retrofitted includes deicers, pavers, scrapers, and dump trucks. In addition, specifications for future new diesel vehicle purchases may include language requiring that oxidation catalysts be installed before delivery.

An example of an initiative to retrofit all public vehicles operating in school districts, public works, sanitation, parks, and other state and local agencies is the New Jersey retrofit program. In February of 1998, Governor Whitman issued an executive order establishing a retrofit program for the states's entire public fleet of highway heavy-duty diesels. Up to 10,000 vehicles will be retrofitted with oxidation catalysts certified under the EPA Urban Bus Retrofit Program. All government owned or operated diesel-powered trucks weighing over 18,000 pounds and built prior to 1994 are eligible to participate in the program. Diesel-powered buses owned or operated by school districts are also eligible. Retrofitting will be conducted free of charge to fleet operators. New Jersey estimates that 400 tons of VOC and 130 tons of PM will be reduced annually when the program is fully implemented. NOx pollution will not be reduced since oxidation catalysts do not reduce NOx.

The above described retrofit programs for state owned heavy-duty vehicles are voluntary. Another means of achieving the retrofit of public fleet vehicles is to mandate the retrofit of state and/or local vehicles by law or executive order.

d. Mandatory Retrofit of State Vehicles: Laws and Executive Orders

While the above described New Jersey executive order does not require the retrofit of all public vehicles (state and local agency participation is voluntary) executive orders can establish mandatory programs. Executive orders have been used in the Northeast states to require the use of alternative fuel vehicles. In 1996, then Massachusetts governor, William Weld issued an order requiring the Department of Procurement and General Services (DPGS) to purchase alternative fuel vehicles in the following percentages:

- 1997 – 10% Alternative fuel
- 1998 - 15% Alternative fuel and 5% zero emission vehicles (ZEVs)
- 1999 - 25% Alternative fuel and 5% ZEVs
- 2000 - 50% Alternative fuel and 10% ZEVs
- 2001 - (and later) 75% Alternative fuel and 10% ZEVs.

The Department of Environmental Protection and the Executive Office of Transportation and Construction have the task of developing and implementing the plan to purchase the minimum alternative fuel and ZEV vehicles. The Massachusetts initiative covers only the purchase of new light-duty government vehicles, however similar executive orders could be issued to require the retrofit of heavy-duty fleet vehicles.

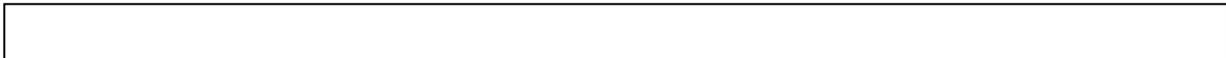
Like the Massachusetts executive order, New York City's Local Law 6 mandates the purchase of an increasing percentage of alternatively fueled vehicles every year. The law states that in each year a progressively greater percentage of alternative fuel vehicles must be purchased by city agencies. The law aims to replace the entire city fleet with alternative fuel vehicles over the next ten years. A similar ordinance could be passed by New York or other cities requiring the retrofit of all state or city owned heavy-duty vehicles.

(1) Structuring Mandatory Programs

A mandatory retrofit project of state owned vehicles might be structured in two phases. In phase one, all state agencies would report back to the agency organizing the retrofit project on the number of eligible vehicles for the program and provide information on the eligible vehicles (engine model year, size, and mileage). In phase two, a schedule would be established requiring a certain percentage of fleet vehicles to be retrofit in each year of the program. Another approach to retrofitting public fleet vehicles would be to adopt a phase-in similar to the proposed New Jersey program. In this initiative, emission control equipment manufacturers are required as part of their contract with the state to develop an inventory of state fleet vehicles, contact fleet operators, and arrange for the retrofitting to take place with oversight from state agencies.

Below, the first of the three example strategies, the retrofit of school buses, is presented. Separate strategies are considered for gasoline and diesel-powered buses due to different available technologies and funding options for the two types of vehicles. A market-based incentive scheme involving the generation of NOx credits which can be sold to finance a retrofit project is discussed. The purpose of the example strategies is to present a method to decide which vehicles to retrofit and how to structure a program. As in the other examples in this chapter, evaluating potential retrofit projects takes place in three steps:

- 1) Determine the contribution of the source to the emissions inventory;
- 2) Determine appropriate retrofit technologies and potential emissions reductions;
- 3) Determine retrofit policy based upon contractual arrangements, ownership, and funding opportunities.

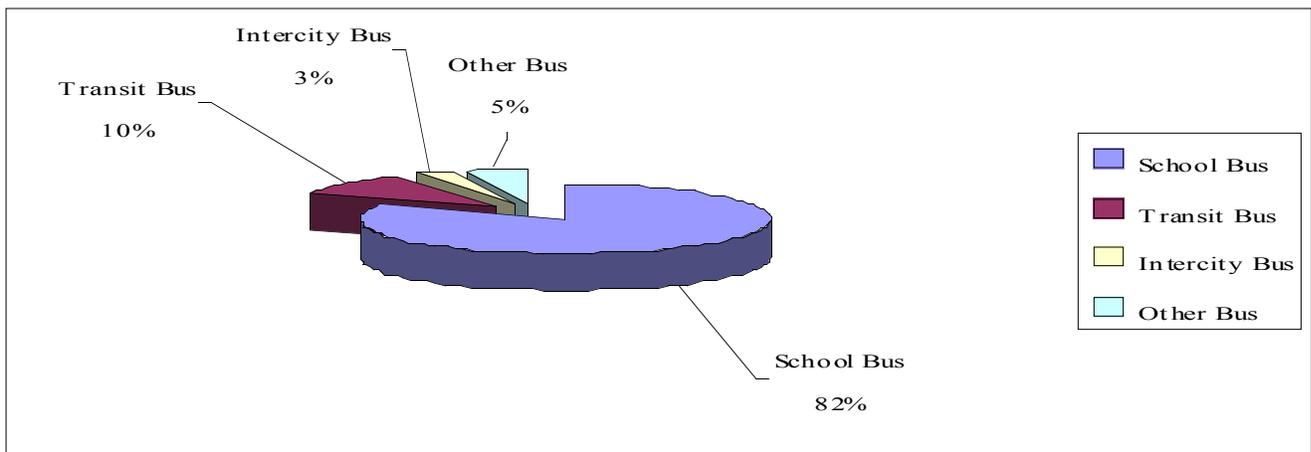


Example Strategy: Retrofit of School Buses

Step One: Determine Contribution to Emissions Inventory

With over 500,000 vehicles in operation nationwide school buses comprise 82% of the total bus fleet (see Figure 1).¹⁵

Figure One: National Bus Population



School buses tend to accumulate fewer miles annually than transit or inter-urban buses but because of their substantial numbers the annual miles traveled by this fleet is significant. Based upon TIUS data and vehicle registration figures in the eight states that comprise the NESCAUM region, there are an estimated 62,000 school buses that travel a total of 682 million miles annually. Emissions data gathered during in-use school bus testing provide a gram per mile NO_x emission rate and TIUS data provide an estimate of annual mileage traveled per bus. Using these data, an approximate amount of pollution can be derived for the Northeast school bus fleet. The following assumptions are made regarding school bus operation:

- 1) School buses drive 11,000 miles per year (TIUS data).
- 2) School buses emit 11 grams of NO_x per mile (in use testing data).¹⁶
- 3) There are 62,000 buses in the region (TIUS data).

Given these assumptions, the total NO_x emissions for all school buses in the NESCAUM states equals 8,255 tons per year, a significant contributor to regional NO_x pollution. In addition, the region's diesel powered school buses emit a significant amount of PM.

¹⁵ "1992 Truck Inventory and Use Survey" (TIUS) Census of Transportation, U.S. Department of Commerce.

¹⁶ Personal communication with Environment Canada and Southwest Research Institute staff.

This pollution disproportionately impacts children who represent a particularly vulnerable group with regard to the adverse effects of air pollution. Protecting school children from bus emissions has become an even greater priority given that the EPA has labeled PM a probable human carcinogen and CARB recently designated diesel particulate as a toxic air contaminant. Further, the need to control school bus emissions is underscored by recent regional monitoring data which indicate that levels of benzene, formaldehyde, acrolein, acetaldehyde, and other toxic compounds are above ambient concentrations that present potential public health concern. Mobile sources, including school buses, are thought to be large contributors to elevated levels of ambient toxic compounds.

Because particulate exposure increases exponentially with proximity to the source, reducing emissions in the vicinity of children provides critical public health benefits. For these reasons, retrofitting in-use school buses with currently available PM, CO, and HC reducing technologies such as oxidation catalysts and catalyzed particulate filters can be an important strategy in minimizing harmful particulate and toxics exposure to children and pedestrians. Furthermore, as compared to other types of heavy-duty vehicles (such as long haul trucks), diesel powered school buses could produce greater amounts of PM due to their operation under “stop and go” conditions which results in higher PM emissions on a gram per mile basis than does a more steady state operation. Consequently for diesel buses, the installation of emission control equipment to reduce PM should be a priority for retrofit programs.

Step Two: Evaluate Technology Options

Several retrofit technology options are available for school buses. The case study will be split into two sections, the first dealing with gasoline vehicles and the second with diesel powered vehicles.

Gasoline Powered School Buses

Approximately 44 percent of the NESCAUM school bus fleet is gasoline powered. Options for retrofitting gasoline engines at this time are limited to three way catalysts (TWCs) such as those used in passenger cars. TWCs reduce NO_x, CO, and HC. Gasoline powered heavy-duty engines have historically not been equipped with TWCs (like passenger cars) because emissions standards for these engines have not been stringent enough to require the use of exhaust emission controls. In addition, there has been a lack of federal pressure to reduce emissions from these existing sources such as that provided for diesels through the Urban Bus Retrofit Program.

At the federal level, gasoline and diesel engines have historically been certified to the same emissions standards. In California, however, CARB has established more stringent standards for gasoline powered vehicles weighing less than 14,000 lbs than for the same weight diesel powered vehicles.¹⁷ EPA is considering promulgating separate standards for gasoline and diesel powered

¹⁷ CARB, The California Low-Emission Vehicle Regulations for Passenger Cars, Light-Duty

heavy-duty engines because of the different potential reductions that can be achieved for diesel and gasoline engines.¹⁸ The more stringent standards being considered by EPA are based, in part, on the fact that TWCs can reduce NOx emissions in gasoline powered heavy-duty engines by more than 80 percent. Existing gasoline engines retrofitted with TWCs could also achieve an 80 percent reduction in NOx emissions.

Diesel Powered School Buses

A retrofit strategy for diesel powered school buses would aim to reduce PM, HC, toxics, and CO. Currently there are no commercially available technologies to reduce NOx from diesel powered school buses. Commercially available retrofit devices and emerging technologies which could in the near future reduce diesel school bus emissions are discussed below.

Oxidation catalysts can reduce particulate emissions by 25% and HC and CO emissions by 50%-90%. Oxidation catalysts are commercially available at this time. Oxidation catalysts are often installed like a standard muffler replacement on a vehicle and require no maintenance. The installation process takes about one hour. The cost for oxidation catalysts ranges from \$500 to \$2,000 per unit.

Catalyzed particulate filters can reduce PM emissions by as much as 90 percent, and HC and CO emissions 50 – 90 percent. While filters have been used widely in the mining and materials handling sectors, they have not been used widely on highway diesel engines. There are two types of particulate filters; passive and active. Passive filters can be installed on vehicles which have high exhaust temperatures (380 degrees centigrade for 25 percent of the time). Most school buses do not have exhaust temperatures that reach these levels. However, a program to determine whether or not this is the case would need to be undertaken before deciding whether or not to proceed with a filter retrofit project. The other type of particulate filter, active filters, do not require high exhaust temperatures. The active particulate systems rely on electrical regeneration of the filter each night and thus requires the availability of shore power. New active filters are being designed so that only twenty minutes of regeneration will be needed for every eight hours of operation. This will still require that a retrofitted bus be near an outlet once every two days (depending upon usage) for 20 minutes. Filters currently cost up to \$10,000, however, economies of scale could reduce this cost to below \$1,000.

Certain fuel additives have been shown to reduce NOx and PM emissions in heavy-duty engines. Increasing the cetane number from 42 to 50 can achieve a 6 percent reduction in NOx emissions, as well as an 8 percent reduction in PM. In addition, several additives are registered with EPA that reduce heavy-duty diesel emissions. Another strategy, emulsion of diesel fuel, has been shown to reduce NOx emissions 30 percent. The use of low sulfur fuel reduces

Trucks and Medium-Duty Vehicles, sections 1960.1, 1956.8, 1965, 2061, 2062 and 2101, title 13, California Code of Regulations, as of February 1, 1999

¹⁸ EPA, "Control of Emissions of Air Pollution from Highway Heavy-Duty Engines" Oct. 1997.

particulate pollution from heavy-duty engines and enhances the performance capabilities of oxidation catalysts and catalyzed filters.

Finally, other potential options for retrofitting diesel buses include selective catalytic reduction and lean NO_x catalysts. However, the application of SCR in mobile sources is very new and thus there is a need for significant pilot program implementation before a large scale retrofit is considered. Similarly, lean NO_x catalysts are still in the development stage and pilot programs for in-use vehicles are needed to evaluate the emission reduction potential of this technology.

Step Three: Evaluate Policy and Funding Options

School districts either own or contract out the operation of their bus fleets. For school buses that are operated by contractors, retrofit could be required as a condition of contract award. For those buses operated by school districts, a retrofit policy could be adopted by the district. Alternatively, legislation could be passed requiring the retrofit of all school buses in-state.

Awareness and concern about school bus emissions varies considerably among school districts. Some cities such as Syracuse, NY and Erie, PA have funded the purchase of compressed natural gas powered school buses in an effort to reduce student exposure to bus emissions. More frequently, school districts have minimal budgets and do not place a high priority on reducing school bus emissions. As a result, in most instances, funding for retrofit projects will need to come from the state or federal government. The need for state and/or federal funding is underscored by the existence of statutes which require school districts to be compensated for complying with mandatory programs. For example, Proposition 2 1/2 in Massachusetts requires that the Commonwealth of Massachusetts fund mandatory programs imposed on municipalities. New Hampshire has similar legislation which reads:

“Any state agency, when administering federal mandates, shall not mandate or assign to any political subdivision any new, expanded or modified programs or responsibilities additional to the federal mandate in such a way as to necessitate additional local expenditures by the political subdivision unless such programs or responsibilities are fully funded by the state or unless such programs or responsibilities are approved for funding by a vote of the local legislative body of the political subdivision” (Part 1, Article 28-a of the New Hampshire Constitution).

In the next section a market strategy for funding the retrofit of gasoline powered school buses is discussed.

Market strategy for funding gasoline powered school bus retrofit

Since gasoline powered vehicles could be retrofitted with TWCs, it might be possible to develop NO_x credits from a gasoline powered school bus retrofit program. Due to the large

number of gasoline school buses operating in the NESCAUM region, there is potential to generate significant mobile source NOx emission reductions through such a retrofit initiative. Table V-1 shows the potential NOx benefits from the retrofit of gasoline powered school buses in the region. Consideration needs to be given to the fact that gasoline powered school buses may not operate during the entire ozone season. In order to properly estimate potential benefits of this retrofit program, surveys of school bus activity during the summer months should be undertaken.

Table V-1: Gasoline School Bus NOx Emissions (NESCAUM Region)

Number of gasoline buses (NESCAUM region)	NOx emissions g/mi per bus	NOx emissions tons/year/bus¹⁹	NOx emissions in tons/year for the NESCAUM bus fleet
27,280	11 g/mi	.13 tons/yr	3,632 tons

Assuming a conservative NOx reduction rate of 80 percent, if the entire fleet of gasoline powered buses in the region were retrofitted with oxidation catalysts, 2,900 tons of NOx could be removed from the region's air each year. Over the life of the buses in the region (assuming they operate for six years after being retrofitted) this would equal a total NOx emission reduction of 17,433 tons.

Below, an analysis of the cost effectiveness of funding retrofits through NOx credit sales is presented. First, the cost of retrofitting with TWCs must be estimated. TWCs can be installed for approximately \$500 per unit on most engine models. For some engine configurations, the retrofit of existing engines with TWCs may also require changes to the fuel system to ensure that the engines run at stoichiometry (balanced air/fuel ratio). These changes would increase the cost of retrofitting from \$500 to \$1,500 per bus. Using these estimates, the cost per ton of NOx reduced is calculated for the retrofit of gasoline school buses and is presented in following table.

Table V-2: Cost Effectiveness of TWC NOx Credit Generation

Cost per bus retrofit	Tons of NOx reduced per bus (over six years)	Cost per ton of NOx reduced
\$500 (without fuel system changes)	.62 tons	\$806 per ton
\$1,500 (including fuel system changes)	.62 tons	\$2,419 per ton

¹⁹ assumes each bus runs 4 hours per day, 180 days per year

At \$806 per ton, the retrofit of gasoline powered school buses represents a very cost-effective NOx reduction strategy, especially compared to other mobile source options. This cost falls within the EPA definition of “highly cost effective” (defined as \$2,000 per ton) methods for reducing NOx emissions under the 1998 Section 110 SIP call²⁰ Where fuel system changes are needed in addition to the catalyst, the cost-effectiveness is calculated at \$2,419 per ton. In this scenario, the cost per ton of NOx reduced is higher than the EPA definition of highly cost effective and thus other options for reducing NOx could be more cost competitive. The above calculations do not factor in reductions in HC that will be achieved through retrofitting school buses with TWC. If these reductions are factored in, the overall cost-effectiveness of this strategy should be even more favorable.

For gasoline powered vehicles, states could initiate a retrofit program which would quantify NOx reductions for possible sale as mobile source emission reduction credits. In addition to selling or trading NOx credits, federal and state funding such as CMAQ, bond initiatives, and other sources could be used to fund a gasoline powered school bus retrofit project.

Given the lack of experience in retrofitting heavy-duty gasoline engines, a pilot program should be undertaken before attempting to implement large-scale retrofit initiatives. A pilot program would: (1) provide more reliable cost estimates for the retrofitting of gasoline school bus engines with three way catalysts; (2) demonstrate the durability and acceptability of the catalyst technology; and (3) verify the emission reductions that can be achieved and the strategy’s cost-effectiveness.

Funding options for diesel powered school buses

Currently available retrofit strategies for diesel school buses do not reduce NOx emissions and thus there is little opportunity to pay for diesel vehicle retrofits through a sale of pollution credits. However, such projects could be funded by CMAQ or other federal and/or state mechanisms. The other options described later in this chapter such as bond issues, supplemental environmental projects (SEP) funds, and dedicated funds could all be used to finance the retrofit of diesel powered school buses in the region.

Summary

The retrofit of school buses offers several advantages over other fleets of heavy-duty vehicles. First, retrofitting school buses would reduce direct exposure to children from heavy-duty vehicle emissions. Second, the buses are publicly owned or operated thus simplifying regulatory action to initiate a retrofit project for these vehicles. Third, the bus engines are similar (approximately 4 models comprise the majority of the 600,000 vehicle engines nationwide). This fact would simplify any large scale retrofit project. Fourth, the buses travel a substantial number

²⁰ FR Vol. 63 pp 57,355 – 57,538, October 27, 1998.

of miles and thus retrofitting would provide a significant environmental benefit. Such retrofit projects would most likely have to be funded by state and/or federal funds.

2. Retrofit of Privately Owned Vehicles

This section discusses strategies for designing, funding, and implementing the retrofitting of private fleet vehicles. The section focuses in part on the legal mechanisms that would be needed and on mechanisms such as cap and trade programs to provide emissions reductions in private fleets. Cap and trade and/or fee based programs would require emissions reductions from fleets which could be complied with through the use of a variety of means, retrofitting being one of these mechanisms.

The federal programs adopted to encourage the use of incentives to reduce mobile source emissions (EIP and VMEP which are described in Section III) assume that states will provide incentives for private fleet operators to reduce emissions from their vehicles. This section discusses both incentives and mandatory programs that states can implement to reduce heavy-duty engine emissions from private fleets. Under VMEP and EIP, the emission benefits from both incentive and mandatory programs could be used for SIP credit purposes. The first section provides a discussion of various incentives that can be provided to private fleets and the second section describes mandatory programs.

a. Market Incentives

Traditional “command and control” approaches to regulating pollution yield emission reductions at a direct financial cost to the regulated entity. Because companies are more competitive when their costs are lower, they have a disincentive to reduce emissions. However, if companies can realize financial benefits or competitive advantage from emission control initiatives, they will have an economic incentive to pursue such reductions. The goal of market-based programs is to provide the incentive to utilize pollution control systems and approaches. From an economic standpoint, market approaches can “internalize” the cost of air pollution. These approaches offer three primary advantages over traditional command and control regulation by:

1. providing an incentive for companies to achieve reductions in excess of the level required by law or earlier than required;
2. increasing compliance flexibility for regulated entities: those that can make reductions cost-effectively, do so; those for whom reductions are prohibitively expensive can turn to the market rather than apply technology; and
3. creating financial value for additional emission reductions that will lead industry to find new solutions to reducing its emissions.

Although considerable progress has been made in developing effective technologies to reduce vehicle pollution, control programs have often fallen short of their full potential. This failure is related to the fact that market signals tend not to reinforce regulations and often actually work against these regulations. For the heavy-duty sector, regulators should examine opportunities to use the market system to induce private and public entities to make transportation choices that are aligned with other societal objectives, including healthful air quality and energy efficiency and diversity. This approach is designed to incorporate the social and environmental costs, currently borne by the general public, into business and government decisions related to transportation.

To maximize the potential impact of incentive programs for heavy-duty vehicles, it is important to understand the fundamental nature of this sector and how it differs from that for light-duty vehicles. For example, since a large portion of the emissions from light-duty vehicles arise from “discretionary” vehicle use, incentives for this sector may target reductions in vehicle use by encouraging individual to either combine trips or pursue alternate, cleaner means of transportation. In the case of heavy-duty vehicles operated almost exclusively for commercial purposes, business-related incentives are already in place to encourage the efficient use of these vehicles and typically have little to do with concerns about air quality. Because the number of trips and mileage accumulated by the fleet represent a basic cost of doing business, companies seek to minimize both in order to maximize their profits. Acknowledging this and other differences provides for a more focused evaluation of market-based options for this sector.

(1) *Preferential Parking*

Parking incentives programs could be initiated by municipalities to provide “clean” heavy-duty vehicles preferential access to the most conveniently located parking spaces. For example, retrofitted vehicles could be given preferential parking on city streets, at airports and other “traffic magnets.” Preferential parking status could be triggered by an emissions level that approaches that of CNG engines (for example). Vehicles meeting the criteria would be given some form of identification for enforcement purposes. Because “time is money,” the provision of preferential parking to reduce travel and wait time could serve as a viable incentive for companies to retrofit some segments of their fleets with emission control devices. The incentive would obviously be greater for fleets comprised of local delivery vehicles.

(2) *“Green” Contracts*

States and/or state agencies may require retrofitting of vehicles operating on public works projects as a condition of contract award. This strategy is important since it greatly expands the numbers of eligible vehicles working on public works projects that can be retrofitted, and it allows for introduction of retrofit devices into private fleets. This approach will be detailed in example strategy B. Another approach is to encourage retrofitting during the bidding process for public works projects. For example, waste hauling, student transport, and street repair/maintenance contracts are often awarded by states and/or municipalities to private fleets. The heavy-duty vehicles in these fleets could be retrofitted with emission control equipment. State and city contracts could include provisions awarding additional “points” on a bid by companies that include retrofitted vehicles in their project fleets. Given the importance of government contract work for many private fleets, properly constructed preferential contract awards appear to represent a potentially strong incentive mechanism. Those companies whose fleets are comprised partly or entirely of retrofitted vehicles would have an advantage over companies with only conventional diesel vehicles not equipped with emission control devices.

(3) *Differential Tolls*

This approach is similar to congestion pricing programs that apply differential usage fees for vehicles using roads, tunnels and bridges, depending on the time of travel. Higher fees are charged during peak traffic hours, with a sequential reduction in the fee as congestion levels are reduced. Under an emissions-based scheme, “clean” heavy-duty vehicles would pay lower tolls than comparable higher emitting vehicles. A process would need to be designed to ensure that only trucks with certified retrofit equipment receive a discount. Such a system would require that electronic debit systems could “recognize” a retrofitted vehicle. This might require significant changes be made to the toll collection system. Program implementation would require up-front capital for public awareness, the development of fee structures and an enforcement program. If fees for dirtier vehicles were increased, the program could be revenue neutral once established.

Recently, congestion pricing has become a reality with the construction of new, private toll roads with variable fees and the installation of electronic toll debit systems in several cities. In New York City, for example, “EZ-Pass” is an automatic debit system used on the toll bridges in the city. Recently, New York initiated a congestion pricing scheme on the Tappan Zee bridge through the EZ-Pass system. During off peak times, trucks are being charged a lower fee to enter the city than during peak times. This fee system could be revised to automatically charge a lower rate to trucks that are retrofitted. The EZ Pass administration would need to keep records indicating which EZ Pass holding trucks are retrofitted. In addition, a system of qualifying emission control equipment would need to be developed. The third party verification process described in Chapters I – IV of this document could be one option for the qualification of emission control devices.

(4) *HOV Lane Use*

High occupancy vehicle lanes are designated freeway lanes reserved for use by vehicles with two or more passengers (buses/van/carpools), often only during peak commuting hours. In some cities, natural gas vehicles are being given access to HOV lanes, regardless of the number of passengers, as an incentive to purchase and use these vehicles. Heavy-duty vehicles retrofitted with certified or verified emission control devices could also be given access to HOV lanes.

(5) *State Tax Incentives for the Purchase of Retrofit Equipment*

In some states, tax incentives have been established for fleet operators who purchase alternative fuel vehicles. Similar incentives could be adopted for the purchase of retrofit devices. A tax credit toward the purchase of a retrofit device would reduce the taxable income for the state taxpayer equivalent to a portion or the full cost of the retrofit equipment. This measure would provide an incentive to taxpayers to purchase retrofit devices which is not realized at the point of purchase, but separately with submission of state income tax forms. Under this measure, the potential savings are not reflected in the purchase price. As a state-wide program, individuals and businesses who do not support retrofit of heavy-duty diesels will be subsidizing retrofit device use through their taxes since the costs of such a measure would be in the reduction of the tax base for the state. As with all state tax credits, the incentive would apply only to vehicles registered in-state.

States could increase the benefit of the above described market mechanisms by offering the incentives as a package. For example, the economic benefit gained from enjoying a lower toll rate may be minimal compared to the cost of retrofitting a truck. However, the economic benefit of variable toll rates, tax incentives, and preferential parking combined could more than compensate a truck owner for the initial cost of a retrofit device.

(6) *Emissions Budgets and Caps*

This section describes the use of budgets and caps to achieve reductions in emissions from projects or activities that employ heavy-duty vehicles. In a budget system, "target" emission levels are established for regulated sources; incentives are offered to over-comply with target levels and disincentives levied against those whose emissions exceed the target. Such schemes are likely to be more cost-effective in the presence of a trading system. Emissions trading among regulated entities encourages the most cost-effective solutions by enabling the regulated community the option of purchasing credits to offset emissions from sources with fewer or more expensive control options. The ability to generate, use and sell emission credits provides the incentive for over-compliance through strategies such as engine retrofit. The primary features of such a trading system include :

- clearly identified source category(ies);
- a target emissions reduction goal for the affected sources over a prescribed time period;
- an allocation system for the distribution of emissions allowances to the affected sources; and
- a monitoring and “true-up” process.

Since the emissions budget approach provides certainty regarding the level of emissions reductions from the targeted sources in a given time period, states are able to rely on emissions budget programs as enforceable control measures in their SIPs. Examples of some possible heavy-duty emissions budget strategies are discussed below.

As explained, market-based strategies are intended to provide an economic incentive to implement control options capable of reducing emissions beyond required levels. Absent the incentive, a less expensive control technology might be selected that nominally meets the emissions limit but fails to achieve surplus reductions. The following examples highlight programs that could be adopted to encourage the use of low emission engine and aftertreatment technology.

(i) Example Emissions Budget Programs

As states begin to implement inspection and maintenance (I/M) programs for heavy-duty trucks and buses, they might consider options designed to encourage the use of emission retrofit technologies. One such option would be the establishment of a variable emission fee system whereby, owners of vehicles not meeting the prescribed limit for a particular pollutant would have to pay a fee and those with emissions significantly below the standard would receive a rebate. To ensure the repair of gross emitters, a maximum emissions level would have to be established.

One approach would involve a two-tiered emission standard concept. The primary standard would represent the ultimate pass/fail level for NO_x and PM emissions; any vehicle failing this standard would have to have the engine repaired and re-tested. The secondary, more stringent standard would be used to assess an incremental emission fee or rebate.

The above described program would depend upon the existence of state heavy-duty vehicle periodic inspection programs for gaseous and particulate emissions. While such programs are likely sometime in the future, states in the region are focused currently on developing smoke inspection programs. A possible approach to establishing an inspection program for NO_x, HC, and CO could be to use existing water break dynamometers in heavy-duty repair facilities in conjunction with the purchase of electrochemical and/or non-dispersive infrared detectors for

NO_x, CO, and HC emissions. Particulate emissions could be measured with a gravimetric method. California has been directed by its legislature to explore options for heavy-duty vehicle emissions testing. The results of the California study could provide states in the Northeast with options for the development of gaseous inspection programs in the region.

The emissions fee approach could also be used in conjunction with the smoke opacity testing programs being implemented in some states and considered in many others in the Northeast and elsewhere. A roadside smoke testing program has the added advantage of covering both in-state and out-of-state vehicles. This approach provides incentives for truck operators to apply any number of control options to their vehicles to limit emissions. Alternatives may include converting a portion of their fleet to cleaner fuels, the purchase of low emitting engines, adding aftertreatment devices, or through improved vehicle maintenance practices. As in the above described program to establish a variable fee system for particulate emissions, this program would establish an incremental emission fee or rebate for smoke emissions from heavy-duty diesel vehicles.

For example, the smoke standards might be set at 40 percent opacity (primary) and 20 percent opacity (secondary). A vehicle emitting 60 percent opacity would fail the test and the owner would be required to repair the emission failure. A truck with a PM measurement of 30 percent opacity would pass the primary standard, but would be assessed an emissions fee based on the product of 10 percent opacity (difference between the measured emissions and the secondary standard) and the number of miles traveled since the last inspection. A truck with a PM measurement of 10 percent opacity would receive a rebate, based on the 10 percent emission rate difference multiplied by the number of miles traveled since the last inspection. These programs could cover both private and publicly owned vehicles. In this program standard opacimeters being used at roadside heavy-duty vehicle inspection stations would be used as the measurement technology. This option may be difficult to implement for several reasons (for example, some states do not test vehicles which are emitting very low levels of smoke) but it does provide an example of how an emissions budget approach could be taken.

b. Mandatory Retrofit Programs for Private Fleets

The above described programs are all market based incentives and thus private fleets would not be required by law to participate. This section describes mandatory programs that states may be able to initiate under the CAAA and state air pollution control laws. States are pre-empted under Section 209 of the Clean Air Act Amendments from requiring controls of new heavy-duty engine emissions. However, Section 209 provides states with the authority to require controls for in-use heavy-duty vehicles. Under the Clean Air Act, states may be able to undertake mandatory retrofit programs for in-use private fleet vehicles as long as the burden of the program falls on vehicle owners, rather than engine manufacturers. However, there is no case

law on this subject and thus a challenge to any mandatory program could constitute a test case. State law must also provide the authority to require retrofit of heavy-duty vehicles.

States have authority to regulate pollution under state air pollution control laws which derive from the police powers of the state to intervene in issues of health, safety, and welfare. Some state air pollution control laws provide broad power to regulate sources which cause or contribute to conditions of air pollution. States with broad power to regulate under the state air pollution control laws have the authority to establish mandatory retrofit programs. States without such broad authority may need additional legislative authority to establish a mandatory fleet retrofit program. States may also have the authority to require the retrofit of heavy-duty vehicles under state motor vehicle laws. Conversely, if a state mandatory retrofit program makes registration contingent upon vehicle retrofit then research will be necessary to ensure that the statute allows for such programs.

Several issues must be considered when states structure engine retrofit strategies for private fleets of heavy-duty vehicles, including: environmental and public health goals; fleet characterization; phase-in mechanisms; and compliance/enforcement approaches. Each of the considerations is discussed in some detail below.

(1) Environmental and Public Health Goals

The size and nature of a heavy-duty engine retrofit program will largely be a function of the pollutants targeted and the level of emission reductions desired. For this sector, the primary concerns are NO_x and particulate emissions. States in the Northeast and elsewhere will need to identify new control options for ozone precursors as part of the SIP process related to the new eight-hour NAAQS for this pollutant. One control option could be to reduce NO_x emissions from diesel generators using currently available SCR technology. There are hundreds of generators located in the region which emit significant amounts of NO_x. Similarly, NO_x reductions from a truck and bus retrofit might represent a viable ozone control strategy.

In addition to NO_x control, achieving reductions in particulates is of interest both for future attainment of the new fine particle NAAQS and to reduce direct exposure to the harmful constituents in diesel exhaust. The first retrofit strategy detailed in this chapter (school buses) would have as its main goal the reduction of children's direct exposure to PM and toxics. This and other projects could be established to reduce urban residents' exposure to PM (like the Urban Bus Program) and to address environmental justice concerns. Given that different retrofit technologies target different pollutants, the goals of the retrofit program must be clearly articulated.

(2) Fleet Characterization

As a first step in crafting appropriate regulations for this sector, states will need to develop detailed profiles of privately owned fleets of trucks and buses. In many states, this

represents a difficult challenge since departments of motor vehicles often do not collect and report fleet information to the level of detail needed for this type of program. Fleet profiles are critical for several reasons. First, they enable regulators to determine the breakdown of engine models powering the fleet in order to assess the availability of appropriate retrofit kits. Second, vehicles with newer and lower emitting engines may not need to be included if the incremental reductions associated with the installation of retrofit technologies cannot be cost-effectively achieved. Finally, the fleet characterization enables regulators to predict the emission benefits associated with a retrofit initiative.

A key challenge to developing accurate fleet profiles relates to the inter-state travel typical of heavy-duty fleet vehicles. Since individual states can only require retrofits for those vehicles registered in their jurisdiction, a significant portion of the heavy-duty vehicles operating on their roadways would not be subject to these rules. Emission inventories for highway motor vehicles are often based on traffic counts taken by state departments of transportation. These counts do not distinguish between vehicles registered in-state and out-of-state. Similarly, vehicles registered in a state with a retrofit requirement may spend a considerable portion of their time operating in other jurisdictions. Consequently, the benefit estimated for a private fleet retrofit program must account for these factors. One approach to this issue could be the establishment of a regional retrofit program. Such a program would facilitate fleet characterization for states and yield increased environmental benefits for all states in the region.

(3) Phase-in Mechanisms

Given the potential adverse consequences of a requirement for all fleet vehicles to comply according to the same time schedule, a phase-in approach would appear preferable for mandatory engine retrofit programs. Several models exist for structuring a phase-in component for such a program. Retrofits could be required only at the time of rebuild or according to a regular schedule based on a gradual retrofit of fleet vehicles. This determination could be predicated on the age of engine models used in fleet vehicles. Alternatively, the scope of the program could be determined according to cost criteria or the availability of a specified number of certified retrofit kits. For example, additional geographic areas or smaller fleets could be brought into the program if the cost of retrofit technology decreased by some pre-determined amount or the number of certified kits exceeded a given threshold.

The phase-in approach used in Stage II vapor recovery programs represents a model that may be adaptable for heavy-duty engine retrofit programs. The Stage II program, requiring filling stations to install evaporative emission control devices on gasoline filling nozzles, was phased-in according to the gasoline throughput total of individual gasoline retailers. While the cutpoints for station size tended to differ in individual state programs, the concept of requiring earlier installation at larger stations was used in most programs. This approach served several purposes: (1) it spread out the compliance period to minimize distribution impacts; (2) it accounted for the fact that only a limited number of contractors existed to conduct the physical

work; and (3) it ensured that the bulk of the emission reductions were realized in the early years of the program. Size thresholds could be incorporated in a mandatory retrofit program using the number of vehicles to determine when each fleet must comply. For example, large fleets of over 100 vehicles might be required to comply in the first year of the program, medium size fleets within three years, and small fleets (under ten vehicles) within five years of program adoption.

(4) Compliance and Enforcement

Given the program similarities, the compliance and enforcement strategies used in the federal Urban Bus Retrofit Program would appear to represent viable options for retrofit programs targeting private fleets of trucks and buses. The Urban Bus Program offers two primary compliance options for fleet operators: a performance-based approach and an emissions averaging scheme. While this initiative targets only particulate emissions, the compliance approaches used would be suitable for other pollutants of interest such as NOx.

The performance-based approach in the federal bus program requires affected vehicles to meet a particulate emission standard of 0.1 g/bhp-hr, effective at the time of engine rebuild or replacement. The requirement is automatically waived if no equipment with a cost of less than \$7,940 has been certified to enable compliance with the 0.1 g/bhp-hr standard. The Urban Bus program contains fallback requirements for “waived” engine families. These waived urban bus engines must be retrofit with equipment that provides a 25 percent reduction in particulate emissions, relative to levels emitted with the original engine configuration. In 1998, the first 0.1 gram technology was certified with the Urban Bus Program, thus providing the technology for compliance with the more stringent standard for many engine families.

The second compliance option within the Urban Bus program is an emissions averaging system requiring affected urban bus operators to meet an annual average fleet particulate emissions level. Under this scheme, each affected fleet operator must meet a declining annual average emission target level for fleets (TLF). The TLF is calculated (in grams per brake horsepower-hour) for each year of the program beginning in 1996. For any given year, the average particulate emissions level from all of the operator’s pre-1994 model year urban buses must be at or below the TLF established for that calendar year. An operator’s TLF for a particular calendar year is calculated as follows:

$$TLF_{CY} = \frac{\sum_{MY=CY-15}^{1993} (B_{MY}) \times (WP_{MY})}{1993}$$

$$\sum_{MY=CY-15} (B_{MY})$$

Where:

CY is the calendar year

MY is the model year

B_{MY} is the number of urban buses of that model year in the operator's fleet as of January 1, 1995, plus any urban buses of that model year added to the fleet after January 1, 1995.

WP_{MY} is the weighted average of projected particulate emissions for urban buses of that model year.

The TLF for a particular calendar year is calculated based on the EPA's determination of the projected emission level for each engine model year in the operator's pre-1994 model year urban bus fleet. Operators must comply with a TLF until all pre-1994 urban buses have been retired from the operator's fleet.

Either of these methods included in the federal Urban Bus program could be adapted by states for enforcing a mandatory retrofit program for private fleet vehicles. Another approach might involve the use of fleet emissions caps as described on page 49. This approach is not necessarily technology-based. Rather, the goal is to reduce total emissions from a fleet through the establishment of an emissions cap and allowing the fleet operator to comply through any combination of emission reduction strategies. Retrofitting would be one of the possible strategies. A detailed discussion of the emissions budget system is included in the following section on nonroad engine retrofitting.

Summary of Highway Vehicle Retrofit Options

This section described several options states can use to introduce retrofit devices into the existing heavy-duty fleet and methods to structure retrofit programs. Some of the descriptions were of actual, ongoing projects and others were hypothetical examples (as in the example school bus retrofit strategy). Some of the options presented can be used now by states to achieve real reductions from heavy-duty vehicles. Others require significant program development.

All of the current retrofit projects being undertaken by states (New Jersey Department of Transportation, New York City Transit Authority, Massachusetts Highway Department, and Manchester Airport programs) are to retrofit public fleet vehicles or fleets that are under contract to state and/or localities. Retrofit of public fleets poses few legal and administrative challenges to states. For this reason, this approach is currently the most viable and represents an important starting point for states that desire to increase the use of retrofit devices. Since a significant

number of heavy-duty vehicles are publicly owned, retrofitting these trucks and buses could provide significant emissions reductions (as is seen from the New Jersey emission reduction estimates) and could establish the viability of retrofit programs. Furthermore, if state and local retrofit programs are expanded to include all vehicles under contract to states, the emissions reduction benefits of retrofit projects can be greatly increased. Expanding retrofit requirements to state contracted fleets also allows for the introduction of retrofit devices into private fleets without the legal and administrative challenges associated with initiating mandatory programs.

The market incentive options outlined in this chapter were hypothetical only but state development of such programs in the future could prove to be important methods for encouraging retrofitting. Market incentive programs, like programs to retrofit state fleet vehicles, do not pose the legal challenges that mandatory programs do and would allow states to encourage the retrofit of private fleet vehicles. Some of the market incentive examples used in the chapter would require substantial program development before they could be considered by states. For example, the fleet emissions cap scheme would require the development of state-wide inspection programs for gaseous and possibly particulate emissions.

The program outlined in this section which would be the most difficult for states to initiate is a mandatory retrofit requirement for privately owned heavy-duty vehicles. Initiating a mandatory program would require legal research into authority to require retrofitting under the CAAA and state air pollution control laws. In addition, such programs would require inter-agency cooperation to set up the legal mechanism for linking retrofit to registration renewal. This is not to say that such programs cannot be undertaken. Rather, mandatory programs represent a long term option as opposed to a near term option.

At this time, retrofit technologies for trucks and buses are limited to oxidation catalysts and, for some vehicles, particulate filters. New applications of existing technologies, i.e.: retrofit of HDD trucks with selective catalytic reduction (as opposed to stationary generators); and TWC use in heavy-duty gasoline engines (as opposed to gasoline passenger cars) may in the future reduce truck emissions by 90 percent. However, demonstrations need to be carried out before these technologies can be broadly applied to truck engines.

The next section describes state programs to encourage the use of retrofit devices in nonroad vehicles such as construction equipment and marine vessels. Since a precedent setting lawsuit significantly restricted states' abilities to require retrofit of nonroad engines, retrofit strategies for these engines are somewhat different than for highway engines.

B. Nonroad Retrofit Strategies

NESCAUM's 1997 report entitled *Heavy Duty Engine Emissions in the Northeast* concluded that nonroad engines emit twenty percent of all NO_x in the region. In addition, EPA

estimates that nonroad engines emit 48 percent of mobile source particle pollution.²¹ Since nonroad equipment powered by diesel engines tend to have relatively long useful lives, retrofit of the in-use fleet appears to represent an important tool for reducing nonroad engine pollution. This section focuses on strategies for reducing emissions from in-use diesel engines used in airport ground support vehicles, construction equipment and marine vessels. These fleets are targeted because they are important components of the NO_x and PM emission inventories in the Northeast and because the nature of their operation lends to a variety of feasible retrofit options. An important constraint when developing in-use strategies for nonroad equipment is the federal preemption precluding states from mandating the retrofit of nonroad engines. The following section describes this preemption and presents various alternatives to mandatory retrofit.

1. State Preemption from Requiring Retrofit of Nonroad Engines

Historically, states have been given authority under the CAAA to regulate in-use engine emissions from mobile sources through inspection and maintenance programs, in-use emissions standards, and other means. However, a recent lawsuit brought by the Engine Manufacturers Association (EMA)²² resulted in a change to the nonroad engine rule which preempts states from requiring the retrofit of in-use nonroad engines to control emissions.²³

In June, 1994, EPA issued regulations covering emissions from heavy-duty nonroad engines. This regulation precluded individual states from adopting regulations governing emissions from new engines. Two years later, in the case Engine Manufacturers Association v. EPA, the DC Court of Appeals held that the preemption extends to both new *and* in-use engines. In 62 FR, EPA states “EPA believes that states are precluded from requiring retrofitting of used nonroad engines...” While this decision imposes considerable constraints on state authority to regulate emission from this sector, states retain some options with regard to reducing in-use emissions from nonroad engines. In the EMA case, the court upheld that portion of EPA’s rule allowing states to regulate the use and operation of nonroad engines. The rule reads:

“EPA believes that states are not precluded under section 209 from regulating the use and operation of nonroad engines, such as regulations on hours of usage, daily mass emission limits, or sulfur limits on fuel; nor are permits regulating such operations precluded, once the engine is no longer new.”

According to the rule, while states cannot explicitly mandate the retrofit of in-use nonroad engines, they can establish programs to encourage the use of engine retrofit technology in

²¹ EPA, “Control of Emissions of Air Pollution from Nonroad Diesel Engines,” 1997

²² Engine Manufacturers Association v. EPA 88 F 3d 1075 (1996)

²³ “Control of Air Pollution: Emission Standards for New Nonroad Compression-Ignition Engines at or Above 37 Kilowatts; Preemption of State Regulation for Nonroad Engine and Vehicle Standards; Amendments to Rules” December, 1997, 62 FR 67733

construction, agricultural and other nonroad equipment such as diesel generators. One alternative is the use of emission caps and/or budgets. With regard to nonroad engines, caps or budgets could be established for individual fleets, for specific projects, or by activity. States are cautioned that daily mass emission limits should not be set so low that it is impossible to comply with them absent the use of retrofits.²⁴

2. Developing Emissions Budgets to Reduce Nonroad Emissions

This section describes the use of budgets and caps to achieve reductions in emissions from projects or activities that employ heavy-duty nonroad vehicles and equipment. The use of economic incentives is likely to be most effective when combined with the establishment of emission caps and/or budgets and they are likely to be more cost-effective in the presence of a trading system. States might consider adopting NOx/PM emissions budgets for nonroad fleets operating within the state or a given nonattainment area. An emissions budget program for these fleets would require: identifying target fleets; establishing a baseline of emissions for the sector; assessing reduction needs and options; establishing the future year emissions target; and allocating emissions to each covered fleet.

To affect reductions from this source sector, the target budget must be carefully calculated to ensure that actual emissions reductions take place. The budget approach, a declining mass emission target, or a declining fleet average emission rate gives the owner/operator the discretion to obtain reductions wherever they can be achieved most cost-effectively. Especially when implemented on a broad scale, this flexibility allows the market to drive demand for cleaner technology and fuels, without agencies mandating specific technologies or reformulations.

Because of the aggregated emissions tracking used by the budget system, reductions that are relatively expensive from some vehicle categories or models can be foregone in favor of less expensive reductions from others. Designing a declining total over time provides ongoing incentives for improvements in emissions reduction options for the affected sources. The effectiveness of this approach is contingent upon the presence of a target source category with units that are of a known quantity, whose ownership/operation is centralized, and that operate within a limited geographic area. These characteristics can be met by certain heavy-duty nonroad vehicles especially construction and marine fleets such as water shuttle ferries.

The lack of good inventories for either nonroad equipment or emissions from these units represents a difficult obstacle to the development of accurate budgets for this sector. A budget system is not viable without good emissions and fleet data. However, the recent work conducted by EPA for their NONROAD emissions model and NESCAUM's efforts to characterize and

²⁴ 40 CFR Part 89 Appendix A of Subpart A. 62 FR at 67736, December 30, 1997

quantify nonroad fleets in the region, provide better data and techniques for improving these inventories.²⁵

a. Retrofit of Airport Vehicles

The collective operations of airport vehicles contribute substantially to emissions of several criteria pollutants. The ability to regulate these emissions has recently become of greater interest to the USEPA, which has begun to work cooperatively with the Federal Aviation Administration (FAA) to evaluate airport-related activities and emissions. Legislation exists that provides an important source of funds to support emissions reductions at airports. In 1990, Congress passed the Airport Improvement Program [49 U.S.C. App. 2202(a)(2)]. The original program provided funding for "any construction, reconstruction, repair, or improvement of an airport (or any purchase of capital equipment for an airport) which is necessary for compliance with the responsibilities of the operator or owner of the airport..." Further authorizing legislation in 1992 added the CAA as one of the compliance obligations for which the program could fund improvements.

The vast majority of airport vehicles are typically fueled by gasoline or diesel. However, pressure to reduce emissions from airport ground service equipment and ground transportation vehicles has begun to mount as a result of the desire to accommodate new flights and more parking. In the 1970's the Massachusetts Federal Implementation Plan (FIP) imposed a parking freeze at Logan Airport in order to reduce emissions from the airport. This parking freeze is still in effect. Analysis conducted for the California's Federal Implementation Plan determined that airports in the affected areas would need to reduce emissions from 20% to 45% from their 1990 levels to meet FIP targets. Effective approaches identified for airports in California could serve as a model for airports in the NESCAUM region. Common airport support vehicles such as forklifts, tugs, sweepers, mobile belt loaders, baggage tractors, de-icing trucks, and push-back tractors could all be retrofitted with commercially available emission control equipment. For vehicles which are not suited to alternative fuel use, retrofits provide a means to reduce emissions.

(1) Airport Emission Budgets

Because as a group ground service equipment at airports emit significant amounts of air pollution, they could be a target sector for an emissions budget strategy. For example, estimates from Logan Airport in Boston indicate that ground service vehicles emit .68 tons of NO_x per day or 278.2 tons per year.²⁶ Where actual in-use data is lacking on emissions from these equipment,

²⁵ EPA, "June, 1998, Draft NONROAD Model," Available Online; <http://www.epa.gov/oms/nonrdmdl.htm>, March 29, 1999 and "Nonroad Engine Emissions in the Northeast," draft NESCAUM report.

²⁶ Boston Logan International Airport 1997, Annual Update, EOE #3247/5146, August, 1998, P 6-8.

the budget could still be designed using best engineering judgement to quantify emissions and activity levels associated with these vehicles. Over time, more accurate information can be gathered and used to refine the budget and reduction targets.

As an example, a NOx emissions budget could be established for a ground service fleet at an airport so that total annual emissions from these units would have to be reduced by a specified amount over time. Assuming a goal to reduce annual emissions by half, an annual cap would be established accordingly. The airport authority or their contractors would be allowed to comply through any combination of controls on the vehicles comprising the regulated fleet. Converting some equipment to very clean alternative fuels, may enable the operators to meet their overall reduction targets without needing to achieve reductions from other equipment where controls are more costly. Compliance demonstrations would be based on hours of operation for these vehicles derived either through monitoring or through a surrogate (e.g., equipment activity multiplied by either an actual emissions rate or an average emissions rate) to determine total emissions.

b. Other Budget Programs

In other budget programs, the company target would be derived from the relative proportion of each individual company's operations or emissions to the category total. The final process used for dividing up total emissions among the affected sources is less important than the ability of the sources and the state to determine whether companies meet their respective targets in future years. For private fleets, such reporting could be based on the use of an average emission rate per vehicle, multiplied by seasonal or annual activity and idling levels.

Each year, the total tons represented by the emissions budget are distributed in the form of allowances to the affected sources. This distribution process can be proportional to each source's contribution to the category's total, as measured by historical, current or expected future emissions, or by historical, current or expected future activity level. Alternatively, the distribution process could be undertaken using an auction approach. At the end of each season or year, each company must hold enough allowances to equal its total emissions. The original allocation to the source may have been adequate to meet this requirement, or it may not. Because the budget program may permit the trading of the allowances, sources holding excess allowances may sell them to sources in need of allowances.

Where a company is capable of making cost effective emissions reductions, fewer allowances will be needed for the true-up step. If allowances are valued at a cost-per-ton that exceeds the cost of reducing emissions, companies have an incentive to undertake reduction measures. As a result, companies with high emissions and high control costs have the option of complying through the purchase of allowances rather than by obtaining reductions in their own

vehicles. Thus, the budget program provides the emissions reductions needed by regulators in a more cost-effective manner for the affected sources.

This approach is less effective for other heavy-duty source sectors whose geographic range of operation would result in emissions occurring beyond the jurisdiction of the regulatory authority implementing the budget program. In such cases, identifying an appropriate emissions budget, proportionally allocating allowances, and "truing-up" is much more complex.

In the following case study an emissions budget approach is identified for private construction projects in the region. An alternative strategy is presented for public works projects.

Example Strategy: Construction Equipment Retrofit

As in the other case studies in this chapter, evaluating potential retrofit projects takes place in three steps:

1. Determine the contribution of the source to the emissions inventory;
2. Determine the appropriate retrofit technologies and potential emissions reductions;
3. Determine the appropriate policy based upon contractual arrangements, ownership, and funding opportunities.

Step One: Determine the contribution of the source to the emissions inventory:

Table V-3: 1998 NESCAUM Region Construction Equipment Emissions

	NOx (tons/yr)	PM (tons/yr)	VOC (tons/yr)	CO (tons/yr)	SOx (tons/yr)
Connecticut	12,475	1,527	2,282	14,665	3,098
Maine	3,821	468	699	4,472	949
Massachusetts	34,447	4,219	6,302	40,519	8,553
New Hampshire	4,462	547	816	5,248	1,108
New Jersey	27,534	3,371	5,036	32,376	6,836
New York	52,884	6,476	9,674	62,192	13,131
Rhode Island	2,597	317	474	3,050	645
Vermont	2,086	255	381	2,434	518
Total tons	140,310	17,184	25,668	164,960	34,841

The above table shows a breakdown of construction equipment emissions in the eight NESCAUM states calculated using EPA's NONROAD model. According to these estimates, construction equipment emits approximately ten percent of all NOx pollution in the NESCAUM region. Although there are fewer heavy-duty construction machines than registered heavy-duty highway vehicles in the region, construction equipment emits almost as much NOx pollution as the region's fleets of trucks and buses. This is because control of nonroad equipment emissions has lagged behind highway engines. Thus, reducing construction equipment emissions could represent an important SIP strategy given the large contribution this sector makes to the overall NOx inventory in the region. Furthermore, since construction machines often operate in densely populated urban areas, reducing NOx and PM emissions from this source is important to reducing exposure to harmful emissions and for environmental justice concerns.

Step Two: Determine Technology Options

Technology options differ for construction equipment depending upon the duty cycle of the engines in-use. This section describes some of the options for retrofitting different types of construction machines.

Earth Moving and other Heavy-Duty Equipment

Typical earth moving equipment such as excavators, backhoes, and bulldozers as well as other heavy equipment such as cranes operate under transient conditions. While NO_x reducing control strategies such as SCR use on backhoes, wheeled loaders, and excavators may be possible in the near future, no demonstrations have been made to date on construction equipment. Since the technology is sensitive to transient modes of operation, demonstrations of the technology need to be conducted prior to widespread use of SCR with construction equipment.

Oxidation catalysts and catalyzed particulate filters can be used to reduce PM, HC, and CO emissions from earth moving equipment. A recent pilot project to retrofit construction machines conducted by NESCAUM, New England Power, and MECA showed that oxidation catalysts reduced PM emissions 23 percent, HC 42 percent, and CO 31 percent. Particulate filters reduced PM by 89 percent and CO and HC 66 percent.²⁷

In addition to oxidation catalysts and particulate filters, other emissions reduction technologies exist such as electronic turbochargers. Turbochargers increase the transient response relative to traditional turbochargers.

Stationary Generators and Similar Equipment

The control options for stationary generators and air compressors include PM, NO_x, HC, and CO emission reduction technologies. Stationary generators are suited to both PM and NO_x reduction strategies due to the steady state operations of the equipment. For PM, CO, and HC reductions oxidation catalysts or catalyzed particulate filters can be used. Other technologies such as electronic turbochargers and low sulfur fuel can be used to reduce PM emissions. Unlike earth moving equipment that operate under transient conditions, generators run at steady state conditions. This makes them suited for retrofit with NO_x and VOC reduction technologies such as selective catalytic reduction. Several field installations of SCR on stationary engines exist and have shown NO_x reductions up to 90 percent.

²⁷ Ainslie, Cooper, McKinnon, Rideout "The Impact of Retrofit Exhaust Control Technologies on Emissions from Heavy-Duty Diesel Construction Equipment" In Diesel Exhaust Aftertreatment, 1999, SAE

Step Three: Evaluate Policy and Funding Options

In this example strategy, construction equipment is divided into two categories: (1) equipment owned or contracted by the states, municipalities, and authorities used on public works projects; and (2) privately owned equipment used on private construction projects. The reason for taking this approach is that policy options differ for equipment used for public works projects and private construction work.

Public Works Projects

Roughly 20% of all heavy-duty construction equipment is involved in public works projects such as road building and sewer/water infrastructure. Such publicly funded construction projects can require or provide incentives for emission reductions by including preferential consideration for contractors with “clean” construction equipment.

An example is the approach adopted by the Massachusetts Highway Department for construction equipment working on the \$11 billion Central Artery/Third Harbor Tunnel project (the “Big Dig”) in Boston. The Massachusetts Highway Department has begun requiring that some new contracts include provisions stating that all diesel equipment will be retrofitted with oxidation catalysts or catalyzed particulate filters. The contract requirement states “contractors must retrofit all diesel equipment 50 horsepower and greater with either oxidation catalysts or catalyzed particulate filters.” The retrofit requirement is placed in the contract section which dictates measures needed for control of diesel exhaust odor. Odor from construction equipment is a source of significant public complaint, and oxidation catalysts and/or catalyzed filters reduce or eliminate odor by lowering hydrocarbon emissions.

In addition to the contract requirement, Massachusetts Highway Department has initiated a 70 machine retrofit initiative. As part of the program, contractors are requested to retrofit approximately 25 percent of permanent equipment operating on the Big Dig. Backhoes, wheeled loaders, excavators, and other machinery will be retrofitted. Massachusetts Highway Department is funding this project. Over a period of six years the project will reduce 203 tons of HC, PM, and CO pollution and 70 percent of toxic emissions such as formaldehyde and benzene.

Emission Budgets for Privately Operated Construction Projects

Retrofitting equipment being used on private projects, such as construction of office and residential buildings, hotels, and other types of construction requires a different strategy. Because states are pre-empted from requiring the retrofit of construction equipment, emissions budgets or caps and/or restrictions on hours of operation will need to be used in order to encourage the use of emission retrofit technology on private construction projects. For construction projects financed by non-government entities, emissions budgets and daily mass

emissions limits could be established for projects exceeding a threshold size, based upon a quantitative measure such as cost.

Calculating Baseline Emissions from Construction Projects

Several methods could be used to calculate baseline emissions from construction projects; one is described below. The method was developed by EPA in its 1991 nonroad study (“NEVES”) and is also used in the new NONROAD model released last year.²⁸ The following information would be needed and could be used by state regulators to estimate baseline emissions for construction projects:

- 1) equipment type
- 2) horsepower
- 3) hours of use per project
- 4) year of manufacture

The formula is as follows:

$$\begin{aligned} & \mathbf{HP \times ALF \times EF \times HO} \\ & \mathbf{=} \\ & \mathbf{\text{grams of pollutant per year per piece of equipment}} \end{aligned}$$

Where:

HP = horsepower of the engine

ALF = average load factor for that type of equipment (from NONROAD model)

EF = emission factor (from NONROAD model)

HO = hours of operation during a given construction project

This formula would be used to calculate emissions for each type of equipment, each horsepower category, and each criteria pollutant. Once the individual calculations have been completed the emissions for each criteria pollutant, equipment category and horsepower are summed to derive a total emissions baseline figure for a construction project.

Once an emissions baseline has been established for a construction project, a declining cap could be established to ensure decreased emissions over time. The following reductions could be established as part of a declining emissions cap:

- Years 1999 - 2004 10% reduction for construction projects in a given nonattainment area

²⁸ EPA “Nonroad Engine and Vehicle Emissions Study Report,” Nov., 1991

- Years 2005 - 2010 20% reduction
- Years 2011 - 2015 30% reduction
- Years 2016 and later 40% reduction

Total emissions from these projects could be capped according to the above listed declining schedule or could be capped proportional to project size, allowing the contractor to obtain the needed reductions in the most cost effective manner. This approach could be extended through the use of a trading mechanism, whereby a contractor would have an incentive to bring the entire project to completion "under budget". The difference between the budget level and actual emissions from the project could be sold as credits to aid in offsetting potential excess emissions associated with another project. Taking a different approach, a bidder who may not be well-positioned to claim cleaner engines or obtain cleaner fuel could achieve equivalent or even greater emissions benefits by purchasing an amount of credits from another emissions source over the life of the project that would equate to a substantial environmental benefit. Construction companies could purchase alternative fuel construction equipment, retrofit in-use engines, purchase equipment with "Blue Sky" engines, or buy pollution credits under the program.²⁹

²⁹ "Blue Sky" engines are EPA certified low emissions nonroad engines

3. Retrofit of Marine Vessels

Although current inventory estimates suggest that marine vessels emit approximately four percent of NO_x emissions in the nation, the impact of these emissions is potentially greater than for other sources for a number of reasons. First, these vessels tend to operate in urban non-attainment areas. Additionally, large marine engines used to power barges, tankers, and other ocean going vessels burn residual fuel which creates greater amounts of toxic emissions than does the burning of number 2 diesel fuel commonly used in smaller marine vessels. Several retrofit technologies are available to reduce criteria and toxic emissions from these engines. As with other sectors, determining the most effective retrofit strategy will entail identifying the appropriate engines for retrofit, the emission control technology to match the engine, and an implementation strategy. This section discusses marine vessel retrofits and presents an example strategy as an example of how such a program could be designed and implemented.

The emissions of primary concern from diesel marine engines are NO_x, PM₁₀/smoke, VOCs, and toxics. They also emit CO and sulfur dioxide (SO₂) at relatively high rates. In the *National Air Pollutant Emission Trends, 1900-1994*, EPA estimated that in 1994, marine diesel engines emitted 158,000 tons of NO_x, 17,000 tons of PM₁₀, and 39,000 tons of VOC. Table V-4 provides a breakdown of national marine vessel emissions by year.

Table V-4: U.S. Primary Pollutant Emissions from Diesel Marine Engines

Year	NO _x (thousands of short tons)	PM ₁₀ (thousands of short tons)	VOC (thousands of short tons)
1970	34	4	8
1980	93	10	23
1985	110	12	28
1986	118	13	29
1987	125	13	31
1988	138	15	35
1989	147	16	37
1990	145	16	36
1991	146	16	37
1992	151	16	38
1993	154	16	38
1994	158	17	39

In 1994, marine diesel engines in the NESCAUM region emitted 1,664 tons PM₁₀, 2,480 tons VOC and 11,464 tons of NO_x. Marine vessel emissions from New Jersey accounted for approximately 70% of all emissions from this sector in the region. Of primary concern is the fact that emissions from this sector are increasing, while those from many other sectors are declining.

a. Marine Vessel Emissions Regulations

To address the problem of increasing marine vessel emissions, the US EPA has proposed new emissions standards for marine diesel engines that will take effect beginning in 2004.³⁰ The rule will significantly reduce emissions from marine engines similar to those used in land based applications (construction and agricultural) and for those similar to locomotive engines over the next two decades. However, for large marine engines much less stringent International Maritime Organization (IMO) regulations will apply. The IMO standards are close to uncontrolled levels and imposition of these standards will only result in an eight percent reduction in large marine vessel NO_x emissions by the year 2030. At the same time, emissions from these slow speed vessels represent the majority of marine vessel pollution in some Northeast ports.

TABLE V-5: Proposed EPA CI Marine Engine Emissions Standards

Engine size	NO _x standards (g/kWh)	PM standards (g/kWh)
Category 1: less than 5 litres displacement per cylinder	Tier II: 7.2 g/kWh Tier III: 4 g/kWh	Tier II: .4,.3,.2 Tier III: no standard
Category 2: 5 –20 litres displacement per cylinder	Tier II: 7.2 g/kWh Tier III: 5 g/kWh	Tier II: .27 Tier III: no standard
Category 3: Greater than 20 litres displacement per cylinder	9.8, 45*n ^(-0.2) , 17 g/kWh	No standards

While the proposed marine engine rule will reduce emissions over the long term for category 1 and 2 engines, retrofitting can reduce emissions in the near term from in-use vessels. Moreover, the proposed EPA rule will not significantly reduce emissions from large marine ocean going vessels and thus retrofitting provides one of the only options for reducing emissions from these category of ships. Below, the third retrofit strategy is presented which details options and technologies to reduce marine vessel pollution.

As in the other case studies in this chapter, evaluating potential retrofit projects takes place in three steps:

³⁰ EPA “Control of Emissions of Air Pollution from New CI Marine Engines at or Above 37 kW, Proposed Rule,” December, 1998.

- 1) Determining the relative emissions contribution from different types of vessels;
- 2) Identifying appropriate technology options; and
- 3) Assessing policy and funding options.

Example Strategy: Retrofit of Marine Vessels

Step One: Determine the contribution to the emissions inventory

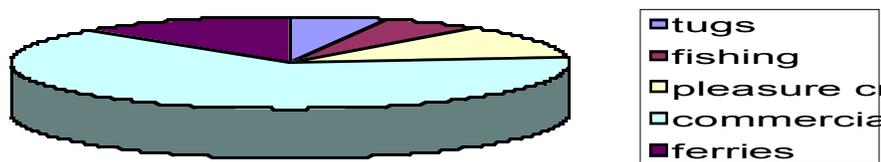
In 1998, NESCAUM conducted a marine vessel emissions inventory for the Boston Harbor. As part of the inventory, data was collected on the numbers of ship arrivals and departures and the length of stay in the Boston Harbor for 1996. Data was collected for commercial, pleasure craft, fishing, and harbor vessels. The following table shows a summary of the numbers and types of marine vessels operating in the Boston Harbor. The table shows that most of the vessels operating in the harbor are privately owned. The major exceptions are military ships and some of the water shuttle ferries which provide commuter services to and from Boston.

Table V-6: Vessel Types in Boston Harbor

Operation/Vessel Type	Ownership/Operators	Number of Vessels
Military	U.S. Navy	500
Construction barges	Corporations	Variable
Pleasure craft	Private owners	2,000
Fishing boats	Private owners	300
Harbor tugs	Boston Fuel Transport	20
Commercial	Shipping companies	1,000 trips per year
Sightseeing	Private tour companies	30
Water shuttle	MBTA, Massport	27

Activity rates and fuel consumption data for the ships was used to calculate emissions for the different types of vessels. Figure two shows the NOx emissions contribution from the most common fleets of vessels using Boston Harbor. Data on vessel activity in Boston Harbor was obtained from “Waterborne Transportation Lines of the U.S.” and from surveys of vessel operators.

Figure Two: Boston Harbor Vessel NOx Emissions by Vessel type



The analysis shows that the majority of NOx emissions come from commercial vessels weighing over 100 tons. While this is the case for Boston Harbor, the composition of the fleet at other ports may vary considerably. For example, Newport, Rhode Island is likely to have a much higher contribution from pleasure craft than from commercial vessels due to the fact that it is a primary destination for pleasure craft boaters. Understanding the composition of the vessels using the facility will help in crafting an appropriate and cost-effective retrofit strategy for a given port.

Step Two: Determine Technology Options

The engines powering marine vessels are well suited to several types of emission reduction technologies. First, commercially available devices such as oxidation catalysts can reduce PM, HC, and CO emissions in marine engines. Oxidation catalysts can be expected to reduce PM by 25 percent on average (if diesel fuel containing 500 ppm or lower sulfur is used), HC 50 – 95 percent, and CO by 45 – 90 percent. Requirements such as sufficient exhaust gas temperatures can generally be met when retrofitting marine engines with oxidation catalysts. Particulate filters could also be used in marine engines to reduce PM emissions by 90 percent where engine exhaust temperatures are sufficient.

Marine diesel engines are also well suited to the use of selective catalytic reduction (SCR) because these engines frequently perform in steady state modes while entering and leaving ports. Maneuvering into berths can require transient operation but this represents a relatively small percentage of the vessel operating time. SCR use in marine engines can achieve extremely low NOx and HC emissions.³¹ When SCR is used in conjunction with an oxidation catalyst, both low PM and NOx emissions can be achieved. Recent incentives established in European ports have spurred the installation of urea SCR systems in a limited number of ships. Table V-7 lists marine SCR applications as of 1996 and shows the level of emission reductions achieved. As indicated in this table, this technology achieves greater than a 90% reduction in NOx.

³¹ HC were reduced by 90% and NOx by 96% “Emission Control in Marine Engines” Diesel & Gas Turbine Worldwide, March 1994.

Table V-7: SCR Use in Marine Vessels Worldwide³²

Ship	Year	Operating area	Ship type	Engine type	Installation type	NOx reduction
Pacific Success	1990	California	Bulk carrier	Two stroke 7.8 MW propulsion	New build	92%
Pittsburgh	1990	California	Bulk carrier	Two stroke 7.8 MW propulsion	New build	92%
Delta Pride	1991	California	Bulk carrier	Two stroke 7.8 MW propulsion	New build	92%
New Horizon	1992	California	Bulk carrier	Two stroke 7.8 MW propulsion	New build	98%
Aurora	1992	Baltic	Ferry	Four stroke 2.5 MW propulsion	New build	98%
Serenade	1994	Baltic	Ferry	Four stroke 3 MW propulsion	Retrofit	90%
Symphony	1995	Baltic	Ferry	Four stroke 3 MW propulsion	Retrofit	90%
Scandica	1995	Skagerrak and Baltic	Supply	2 x 4 stroke 1.3 MW propulsion and 4 x 4 stroke .25 MW auxiliary	Retrofit	96%

SCR can be used with relatively high fuel sulfur levels (1 percent by weight) but such high sulfur fuel may have an impact on the durability of the emission control equipment. Four ships equipped with SCR technology are currently running on 1 percent sulfur fuel. Other ships are operating on lower sulfur fuel ranging from 1 percent to .05 percent.

The experience to date suggests that it takes from ten to fifteen days in the shipyard to install an SCR unit. The SCR reactors can be tailor-made for a particular application, with consideration for space concerns. The SCR unit can be delivered in sections so as to fit through existing passages. Equipping marine auxiliary and propulsion engines with SCR is generally thought to be technically feasible and reasonable in cost.

Step Three: Determine Policy Options

As indicated in Table V-6, most of the marine vessels operating in Boston Harbor are privately owned. Figure Two showed that most of the emissions come from commercial vessels, pleasure craft, and tugs. However, commuter ferries represent a significant source of emissions at this port. These ferries are operated by public entities: the Massachusetts Port Authority (Massport) and the Massachusetts Bay Transportation Authority (MBTA).

³² Table reproduced from "Warship Application of Compact Selective Catalytic Reduction Plant for Diesel Exhaust Emission Control" Lt. Cdr B L Burlingham, BSc, Ceng, MIMarE, RN, The Institute of the Marine Engineers' Third International Naval Engineering Conference and Exhibition, April, 1996.

Different retrofit strategies might be considered for private and public fleets operating in the Boston Harbor. State preemption of mandatory nonroad engine retrofit limits the options for privately owned vessels. Consequently, an emissions cap or fee program could represent the best approach for reducing emissions from the private fleet. Conversely, more direct strategies such as mandatory retrofit requirement may be viable for publicly operated ferries.

Retrofit of Publicly Operated Vessels

Public agencies or quasi public authorities such as the MBTA and Massport could set an emissions performance standard for vessels operating under agency or authority contract. Currently, three companies operate a total of twenty vessels year round and each have three year contracts with the MBTA or Massport. A performance standard could be adopted for new

contracts. The EMA court decision specified that caps must be set at a level which does not specifically require retrofit of marine vessels. A sufficiently stringent performance standard could be developed which could be complied with through the use of a variety of technologies, such as compressed natural gas, retrofits, reformulated diesel fuel, and other control strategies. The operator would choose which control technology to use based on cost effectiveness and ease of implementation. A potential model for commuter boat emissions standards is as follows:

Table V-8: Proposed Emissions Performance Standard

Medium speed boats 130 rpm ≤ n < 2000 rpm	Proposed Performance Standard (g/kW-hr)³³	Current Annual Emissions	Annual Emissions with new standard
NOx	1.95– 5.1	176 tons per year	52 tons per year
VOC	Ap42 * .3	93 tons per year	28 tons per year

Use of Emission Reduction Credits to Fund a Retrofit Project

Another potential method to encourage retrofit of ferry boats would be linking the ferry retrofit to emission reduction credit (ERC) generation. The retrofit credit method established for EPA’s VMEP program could provide the basis for ERC calculation. Currently 30 power plants in the region have or soon will request new permits. Some of the emission reductions required for the permitting of these facilities could be supplied by mobile source emission reduction credits.

³³ EPA “Compilation of Air Pollutant Emission Factors” Vol. I: Stationary, Point, and Area Sources, Fifth Edition, January, 1995.

Power plant operators could group several mobile source emission reduction programs in order to generate enough emission reductions to comply with their permit requirements. The mechanism for such a program could occur in several steps. First, the power plant would agree to the retrofit option and provide funding for the equipment purchase and installation. Then a credit calculation would be developed. The retrofit would be in place for one year at which time the power plant would submit an estimate of emission reductions that occurred during the first year. For every year afterward, the power plant would submit data on hours of operation at full load and idle to substantiate emission reduction claims. This option would only work in the case where the ferries were operating close to a site that required offset credits in order to be permitted by the state. Significant work would need to be done to establish an enforcement mechanism for this credit generation scheme. Below, the cost benefit of establishing NOx credits through an SCR retrofit program are detailed.

Table V-9: Costs of SCR Retrofit

Engine horsepower	Catalyst Cost	Urea Tank Cost	Injection Cost	Annual Urea Cost
750 hp	\$7,000	\$1 per gallon capacity	\$8,500	FC*.06*.7
3,000 hp	\$20,000	\$1 per gallon capacity	\$12,500	FC*.06*.7

Table V-9 details SCR system hardware, tankage, and injector system costs as well as a method for calculating annual urea cost. The urea cost is calculated by multiplying the annual gallons of fuel consumed (FC) by six percent (the average consumption of urea is approximately 4 to 6 percent of total diesel fuel consumption). This product is then multiplied by the cost per gallon of urea (70 cents) to predict annual costs. For a boat that consumes 150 gallons of diesel per day, the urea cost would be \$6.30 per day or \$2,299 per year. The capital costs for the SCR retrofit would be approximately \$16,000 per 750 horsepower engine.

Assuming all 27 of the Boston Harbor commuter ferries were to be retrofitted to achieve a 70 percent NOx reduction rate, then approximately 123 tons of NOx would be reduced each year. Over five years this reduction would equal 616 tons of NOx. If all 27 vessels are retrofitted at a cost of \$864,000 (assumes two 750 hp engines per ship are retrofitted at a cost of \$16,000 per engine) then the cost per ton of NOx reduced over the five years is \$1,402. If the SCR systems remain on the ships for longer than five years then the cost would be reduced substantially. For example, if the SCR systems are operational for seven years the cost per ton is reduced to \$1,000. This estimate does not include the annual cost of the urea or potential administrative costs.

Fee based program for reducing emissions from private vessels

The credit generation scheme presented in the last section was developed for publicly operated ships. The scheme relied in part on contract requirements to reduce marine vessel emissions. In some ports, large privately operated commercial vessels are the greatest source of NOx. For example, ocean going tankers and cruise ships emit 60 percent of the NOx and PM pollution in the Boston Harbor. As mentioned at the beginning of this section, current IMO and EPA proposed emissions standards will not significantly reduce pollution for these large vessel engines. Therefore, state programs to encourage emission reductions from these ships are needed if emissions reductions are to be achieved. The following section describes an existing variable fee system that could be used as a model for Northeast ports.

Swedish Fee Program³⁴

Over 95 percent of Sweden's foreign trade is seaborne and water ferry traffic between Swedish and foreign ports is substantial. In 1996 The Board of the Swedish Ports' and Stevedores' Association reached agreement with the Swedish Maritime Administration (SMA) and the Swedish Shipowner's Association to reduce marine vessel NOx and SOx emissions by 75 percent beginning in the year 2000. The agreement established environmentally differentiated revenue neutral fees based upon NOx emissions and the sulfur content of the fuel used to power the vessels. In the first eight months of the program, nearly one thousand vessels were operating on low sulfur fuel. SCR and other NOx reducing technologies have also been introduced in several vessels as a result of the program.

Ferries using 0.5 percent by weight sulfur fuel and commercial vessels using 1.0 percent by weight sulfur fuel are given a rebate on fees. Those using fuels with sulfur levels above 0.5 and 1.0 percent pay a fee that is proportional to the sulfur content of the fuel. The differentiation of shipping lane dues is intended to eliminate the financial advantage of using high sulfur fuel and encourage more vessels to convert to cleaner-burning fuel. Fees are also differentiated according to NOx emissions. For ships with emission rates lower than 2 g/kWh NOx, fairway fees will be reduced by 95 percent. For ships with NOx emissions between 2 g/kWh and 12 g/kWh, fees will be assessed in a linear fashion at some level below historic rates. Vessels with emission rates above 12 g/kWh, will be levied fees that are higher than historic rates. Low NOx technologies being considered for use in this program include SCR and emulsion.

³⁴ "Environmental Differentiated Fairway and Port Dues" Swedish Maritime Administration, Sjöfartsverkets tryckeri, Norrköping 3357-98

The SMA, in conjunction with the Swedish Ports and Stevedore's Association, is developing an information system for classifying ships that harbor administrators will be able to access when they are assessing fees. All ships using low sulfur fuel and those equipped with catalyzers to reduce NOx will be certified and registered in the information system. The SMA is also encouraging Swedish port administrators to work with foreign ports which share frequent ferry traffic to encourage the implementation of environmentally differentiated fee systems in their ports.

Defraying the Costs of Low NOx Technology Installation

As an incentive to help defray the costs of installing SCR or other NOx reducing technologies, ships with certified low emitting engines will be exempt from paying certain fees (such as lighthouse fees) for two years. These fee exemptions will refund 40 percent of the low NOx technology cost if they are installed before the year 2000 and 30 percent if they are installed afterward.

Boston Harbor Fees

Various fees are levied on commercial vessels entering and leaving the Boston Harbor such as those for pilot assistance and for use of port facilities and berths. Like the Swedish fee system, these charges could be replaced with environmentally differentiated fees. As with other mobile source market incentive programs, developing a regional fee system would be preferable to a local incentive program. This is especially true with ports since they often compete for shipping traffic. Thus, it may be beneficial for port emissions fee systems or emissions caps to be developed on a regional basis so that individual ports will not be penalized for their efforts to reduce vessel pollution.

Summary of Nonroad Retrofit Strategy Options

This section described several options states can use to introduce retrofit devices into the existing heavy-duty nonroad fleet and possible methods to structure retrofit programs. At this time, one nonroad retrofit project is being undertaken in the region (Massachusetts Highway Department program). Additionally, other states are considering nonroad retrofit projects. All of the projects being considered or undertaken are aimed at mitigating the environmental impacts of large construction projects. The programs will rely on funding from public agencies or on funding from companies who are undertaking the projects. In order to initiate nonroad retrofit programs, states and localities could retrofit their own nonroad equipment operating in public works departments and landfills (for example). They may, as well, have leeway in requiring the retrofit of nonroad equipment used on public works projects. The Central Artery/Tunnel project in Massachusetts provides an example of a state agency requiring retrofit of nonroad engines through contractual arrangements. Retrofit projects can be also be encouraged as part of an environmental impact review process. These types of initiatives are the most viable at this time.

As described in this section, states are pre-empted from requiring retrofit of nonroad equipment by the EMA court decision of 1997. As a result of this decision, states cannot require retrofit of nonroad engines as they can for highway heavy-duty vehicles (as a prerequisite for vehicle registration, for example). The EMA court *did* allow for other emission reduction

strategies which could indirectly result in the retrofitting of nonroad engines. For example, emissions caps can be established which could be complied with through a number of approaches including: restricting hours of use, retrofitting, use of vehicles powered by Blue Sky engines, fuel improvements, and other means. While requiring retrofit of nonroad machines as a condition of contract award may not fall under the state preemption from requiring nonroad retrofit, the law has not yet been tested.

The chapter provided ideas on how emissions caps could be developed (construction example study, and declining caps for highway vehicle fleets). However, these ideas are only theoretical at this point and require considerable thought and development before they can be initiated by states. Important issues to consider when developing emissions budgets for construction projects are the short time frame of the projects and the changing types of equipment used during construction. States may wish to consider developing emissions budgets and caps for other types of nonroad engines that may lend themselves more easily to an emissions budget approach. For instance, marine vessels on contract to states or state agencies may produce predictable emissions over long periods of time (ferries or tug boats for example). These vessels may be easier to develop emissions budgets and caps for than construction machines.

The technologies available for retrofitting nonroad engines at this time are oxidation catalysts, fuel changes, and in some cases particulate filters. For stationary generators and some marine engines selective catalytic reduction can be used to achieve significant NOx reductions.

C. Funding Opportunities for Promoting the Retrofit of HD Engines

A variety of potential sources exist to fund the retrofitting of heavy-duty diesel engines with emission control devices. The section describes the following specific mechanisms and cites examples of current initiatives that rely on these sources of funding:

- Congestion Mitigation Air Quality Improvement Funds (CMAQ)
- Clean Air Partnership Fund
- State Bond Issues
- Earmarked State Funds
- Supplemental Environmental Projects (SEPs)

1. Congestion Mitigation Air Quality Improvement Funds (CMAQ)

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) and the re-authorized 1998 Transportation Equity Act for the Twenty First Century (TEA-21) include important planning and financial tools to assist states in achieving the broad goals of the Clean

Air Act (CAA). ISTEA provided an enhanced transportation planning process for state and metropolitan government that was both more flexible in terms of multi-modal options and better integrated with the air quality planning process. TEA-21 extends this planning process through the year 2004.

TEA-21 also continues the Congestion Mitigation and Air Quality Improvement (CMAQ) program established under ISTEA. This program provides states with substantial federal funds to support transportation projects that reduce motor vehicle emissions and contribute to attainment of the National Ambient Air Quality Standards (NAAQS). The Act targets \$8 billion for CMAQ programs and projects. Funding is apportioned to states according to a formula that accounts for the population of nonattainment areas and the severity of their air quality problem. CMAQ is funding the New Jersey retrofit project described in the first section of this chapter and could be used to fund similar retrofit programs for heavy-duty vehicles in other states.

2. Proposed Clean Air Partnership Fund

EPA's proposed Clean Air Partnership Fund would earmark \$200 million every year for five years in "new resources for states, cities and tribes to reduce soot, smog, air toxics and greenhouse gases that contribute to climate change. The money would go to new anti-pollution technologies. It would foster public-private partnerships that help communities achieve their clean air goals sooner than required." The establishment of this fund is contingent upon Congressional approval of the proposed federal budget for the year 2000. If this fund is established it could provide significant support for state retrofit initiatives to reduce heavy-duty engine pollution.

4. State and Authority Bond Issues

State and municipal governments as well as authorities (such as port authorities) can be granted the power to issue bonds from state legislatures. In some states, state law requires that a ballot initiative be approved by the public. The law varies state to state on the types of entities that can propose a bond issue and the extent to which bonds can be used to fund projects. Generally, state legislatures either authorize a specific bond issue through legislation or they establish a group, such as an authority, with the power to issue bonds. Some combination of the above two options also takes place in some cases when bonds are approved.

When specific bond issues or the authority to issue bonds has been approved by the legislature, bonds are sold and the funds are used to raise money for public works such as road, sewage and water system, school, and public transportation improvement projects. In addition to public works projects, bonds can be proposed to fund other programs, such as environmental

initiatives. State funding in the form of bond issues can and are providing important support for state retrofit projects. Specific bond initiatives supporting retrofit projects in the Northeast are described below.

The New York legislature voted in 1998 to approve a 1.75 billion dollar bond act to be used for environmental projects. The bond proposal was submitted to the legislature by New York governor, George Pataki. Funds for clean water and safe drinking water projects total \$1,145 billion, \$230 million is allocated to air quality programs and \$375 million is allocated to solid waste and municipal environmental restoration projects. The clean air projects include government clean fueled vehicles and associated infrastructure; the purchase of alternative fuel buses or the conversion of diesel buses to alternative fuels and the development of requisite infrastructure.

The Manchester Airport retrofit project described earlier in this chapter is also being funded by a bond issue. The bond is funding the expansion of the airport, and it will also be used to cover the costs of the retrofit devices and installation.

5. Dedicated or Earmarked Funds

Another option for financing retrofit projects is to dedicate a percentage of registration fees and/or penalty moneys associated with heavy-duty vehicles for the installation of emission control devices. The California initiative described below explains how one such program works. Other types of dedicated funds could be established from penalty monies from parking and traffic violations. These funds could be used by states and or private groups for retrofitting fleets. For example, certain commercial fleets accrue millions of dollars in parking tickets annually. A percentage of these fines could fund the retrofit of a significant number of vehicles.

The California legislature recently passed two bills authorizing the establishment of the Carl Moyer Memorial Air Standards Attainment Program. The Program allocates over \$25 million for the purpose of reducing emissions from heavy-duty highway and nonroad vehicles and machines. SB 1857 describes the funding mechanism and AB 1368 describes the types of technologies that are eligible for funding through the program. The re-powering of diesel engines with cleaner, new engines, alternative fuel vehicle purchases, and the retrofit/rebuild of in-use engines are eligible for funding. Locomotive and marine vessel emission reduction projects are also eligible.

SB 1857 delegates administration of the program to the air pollution control districts, air quality management districts, and port authorities who can apply for funds. The bill requires that civil penalties recovered by the State Air Resources Board from owners and operators of heavy-duty diesel motor vehicles with excessive smoke emissions be deposited in a specified account in the general fund. In addition, the bill would appropriate \$50 million from the general

fund to the Carl Moyer fund, which will be available for expenditure without regard to fiscal year.

6. Supplemental Environmental Projects

Violations of state and federal environmental statutes can result in the levying of substantial civil penalties. Typically the penalties are in the form of fines allocated to the general fund. Occasionally, a portion of these fines are earmarked for Supplemental Environmental Projects (SEPs) with a nexus to the violation. SEP funds from both federal and state enforcement actions could in some cases be used to fund retrofit projects, as in a recent federal enforcement action against seven heavy-duty engine manufacturers.³⁵

The recent consent decree between the United States and seven heavy-duty engine manufacturers may provide funds for retrofit projects to satisfy, in part, injunctive relief sought by the federal government for excess NO_x emissions from highway heavy-duty diesel vehicles. The consent decrees establishes \$109 million for the implementation of environmental projects intended to mitigate the effects of over one million heavy-duty engines that have or will emit 15 million tons of excess NO_x. Engine manufacturer proposed SEPs include nonroad and highway SCR and lean NO_x catalyst projects. In addition, compressed natural gas projects have been proposed.

While some of the projects in this consent decree will be conducted exclusively by the engine manufacturers, proposals received from states and other interested groups will be considered for funding. A total of \$22 million in potential funding for proposals submitted during the comment period will be considered by the engine manufacturers and by EPA for funding. Retrofit projects could be strong candidates for SEP monies. The above described settlement is the largest in Clean Air Act history and could provide millions of dollars for retrofit projects.

Another example of a litigation related environmental project is the retrofit of marine vessels in California which resulted from labor groups contesting an environmental impact statement. The retrofit of marine vessels was carried out voluntarily by the company as a result of the litigation. This program is described below.

In San Francisco, the Bay Area Air Quality Management District (BAAQMD) imposed a limit of 220 kg of NO_x for USS-POSCO Industries (UPI) ships as part of a settlement related to the environmental impact statement for a plant expansion. As a result, four vessels traveling

³⁵ U.S. v. Cummins Engine Co. Civil Action No. 98-2546, U.S. v. Detroit Diesel Corporation, Civil Action No. 98-2548, U.S. v. Caterpillar, Inc., Civil Action No. 98-2544, U.S. v. Mack Trucks, Inc. No. 98-1495 and U.S. v. Renault Vehicules Industriels No. 98-2543; U.S. v. Navistar No. 98-2545, U.S. v. Volvo Truck Corp. No. 98-2547.

from Korea to San Francisco were equipped with SCR units. The vessels routinely travel 48 nautical miles within the BAAQMD jurisdiction which begins five miles west of the Golden Gate bridge. Two to three hours before arrival at the BAAQMD boundary, the main engine fuel is switched from normal heavy fuel to an ultra low sulfur marine diesel oil. The use of low sulfur fuel allows for the SCR system to be effective during a wider range of exhaust gas temperatures than it normally would be. This is important for the California bound ships because their operations are frequently transient in nature while maneuvering in the Bay. This settlement and the resulting environmental project is similar to a supplemental environmental project.

7. VMEP Program and SIP Credit Calculation

The policy and funding mechanisms described in this chapter outline ways that state staff can think about and implement retrofit projects for heavy-duty engines. The federal government has established significant sources of funding to encourage this and other emissions reduction projects. In addition, EPA recently established the Voluntary Mobile Source Emission Reduction Credit Program which allows states to claim SIP credits from voluntary mobile source emission reduction projects, such as retrofit projects. The retrofit programs described in this chapter could be eligible for SIP credit generation under this program.

In October 1997, the OMS released “Guidance on Incorporating Voluntary Mobile Source Emission Reduction Programs in State Implementation Plans.” The voluntary measures guidance applies to innovative mobile source air quality programs that are voluntary *or* that are operated by a non-governmental entity. This is a pilot program currently undergoing a 5-year trial, and will be re-examined in 2002. Potential voluntary measures programs include employer-based commuter choice, mobile source public education/outreach programs, small scale financial mechanisms (those producing relatively small emission reductions), “ozone action day” programs, and community-based transportation programs. State staff may find either the Economic Incentives Policy (EIP) guidance or the voluntary measures guidance to be more appropriate depending on the specific nature of the program. If states submit a program to the EPA under the *voluntary measures guidance*, they do not need to follow the EIP guidance.

The EPA has limited the administrative requirements of programs developed under the voluntary measures guidance because these programs are smaller in terms of the emission reductions they produce, and because they can increase public awareness. States may use the voluntary measures guidance to achieve up to 3 percent of the required reductions for each of the criteria air pollutants or precursor for any applicable SIP requirement. The 3 percent cap per criteria pollutant was instituted because states are not required to play a direct role in implementing these programs, the programs are not directly enforceable against participating parties, and there may be less experience in quantifying the emission benefits from these programs. Under the voluntary measures policy, state agencies must make a commitment that the program

is conducted and monitored, and that states will make up for any reductions which are claimed but not achieved by the program.

States may use the EIP guidance to implement programs which will generate emission reductions beyond the 3 percent limit, or when state programs have already reached the 3 percent limit under the voluntary measures guidance. Under the EIP Guidance, states are directly responsible for ensuring that program elements are implemented. A program must be directly enforceable as described in sections 5.0, 7.1, and 13.2 of the federal guidance. Actions and/or emission reductions by identifiable sources are enforceable by states and/or by the EPA.

To determine the best policy for a program, consider the following.

- Who will implement and operate the program.
- The size of the program, and the cumulative size of all programs the state has developed under the voluntary measures guidance
- The enforceability of the program.

In general states should use the EIP guidance to implement transportation pricing programs (e.g., roadway pricing).

Chapter Summary

Heavy-duty engine emission control has lagged behind control of other sources such as passenger cars and stationary sources. This lack of emissions control is compounded by the durability of diesel engines. For example, estimates from registration data in the Northeast indicate that 40% of trucks in the region are pre-1989 model year, and thus are uncontrolled for particulates. In the case of nonroad engines, the disparity is even greater, given that all pre-1996 engines are uncontrolled. Due to this disparity in in-use emissions between heavy-duty vehicles and other sources, heavy-duty engines contribute disproportionately to the emissions inventory for NO_x, PM, and toxics. As states work to attain air quality standards for these pollutants they will increasingly look to the heavy-duty engine sector for reductions. Retrofit of in-use heavy-duty diesels provides a means for states to reduce PM, CO, HC, and, in some cases NO_x, emissions from these engines. Controlling heavy-duty engine pollution could be the most cost effective way to reduce NO_x and PM at this time as compared with further control options for cars and stationary sources.

Options for reducing PM, HC, CO and toxics include oxidation catalysts, fuel changes, and particulate filters. While ambient standards for fine particulates may not require states to reduce PM levels, public concern over smoke, odor, toxics, and PM from diesels *has* spurred efforts to reduce diesel emissions such as retrofit initiatives. States are beginning to address public concern over diesel pollution by initiating retrofit projects. Public concern over diesel

emissions is often most pronounced in urban areas where residents are disproportionately impacted by construction projects, marine vessel emissions and highway diesels. For this reason, targeting fleets or projects for retrofit for which there will be substantial community support can be important to the success of retrofit initiatives. The Central Artery/Tunnel project is an example of a project which grew out of community concern over diesel emissions.

While the retrofit projects to date are geared toward reducing PM, HC, CO, and toxics, in the future retrofit projects to reduce NOx emissions from heavy-duty diesels could achieve significant reductions. For example, the studies in this chapter showed that reducing NOx from school buses and from marine vessels costs approximately \$800 to 1,500. The development of emulsified fuels, additives, lean NOx catalysts, and NOx adsorbers may provide states with more options to reduce NOx from heavy-duty engines in the future. While these options require research and development, other options are feasible at this time. For example, the retrofit of stationary generators with SCR provides an opportunity to reduce NOx emissions from the hundreds of generators operating in the region.

The development of mobile source emission reduction credits for NOx could also encourage retrofit of heavy-duty diesels in the future. The chapter listed several options for generating NOx credits. A quantification mechanism and a method for trading these potential credits, however, needs to be developed. Appendix A details CARB's guidelines for credit generation which could be used by the Northeast states as a starting point in developing a credit generation and trading program.

In the case of all retrofit projects, states need to assess the potential emissions reductions opportunities available and then choose implementation strategies. The chapter provided a number of ideas as to how this can be done.

The chapter listed a host of potential sources to fund heavy-duty engine emission control retrofit initiatives. Some, like the federal CMAQ program are already available to states. As outlined above, states and local governments have a variety of other mechanisms at their disposal to fund such projects. Bond issues, earmarked funds and supplemental environmental penalties are currently being used by some states to fund retrofit programs. These funds can and are being used by states to initiate highway and nonroad retrofit projects to reduce in-use heavy-duty diesel pollution.

Appendix A

Credit Generation for Trading Purposes

CARB Guidelines for Mobile Source Emission Reduction Credits

The California Air Resources Board has provided guidance to the 34 air quality management districts of the state for the development of mobile source emission reduction credit (MSERC) program. These guidelines are substantively consistent with the 1986 USEPA Emission Trading Policy Statement for Emission Reduction Credit (ERC) trading; that is, they require that the reductions be surplus, quantifiable, permanent and enforceable.

Specific district programs are discussed below.

South Coast Air Quality Management District Strategy #1: Rule 1612 - Clean On-Highway Vehicles (September, 1995)

Description: voluntary reductions of NO_x, HC, CO, PM and SO_x emissions to create MERCs through the operation of low- or zero-emission on-highway vehicles within the boundaries of the District.

Applicability: passenger cars, light-duty trucks, medium-duty vehicles and heavy-duty vehicles that are registered and operated in the District for which optional emission standards have been set by CARB.

Eligibility:

- operation of a new heavy-duty vehicle, powered with engines certified to optional emission standards
- operation of repowered heavy-duty vehicles with engines certified to optional emission standards
- operation of heavy-duty vehicles, retrofitted to comply with optional emission standards using certified conversion kits and using manufacturer approved facilities for the installation of the certified conversion kits
- operation of new low- or zero-emission heavy-duty vehicles that results in evaporative and marketing loss emission reductions.

The vehicle operator must submit an application for MERCs which includes a description of the repowering, retrofitting or purchasing project, and information characterizing both the baseline engine and the new engine. Each year, the operator must submit actual vehicle miles traveled documentation and ensure that all engine replacement and major engine overhauls are performed

in accordance with specifications and procedures required by the engine or retrofit manufacturer throughout the engine's life.

Credit life/discounts/design margin: MERCs are not discounted at the time of creation. They expire two years after the date of issuance and are discounted by 20% at the time of use, unless the use already provides for an offset ratio of greater than 1.0. Use must occur in the same District in which the MERCs were created.

Strategy #2: Rule 1620 - Clean Nonroad Mobile Equipment (March, 1996)

Description: provides opportunity to generate NO_x, HC, CO, PM and SO_x mobile source emission reduction credits on a voluntary basis through the operation of low- or zero-emission off-road equipment within the District.

Applicability: any off-road mobile equipment or vehicle for which emission standards have been adopted by CARB or EPA and for which optional emission standards have been specified. Such equipment and vehicles would be used primarily off-highway to propel, move, or draw persons or property in construction, commercial, industrial, mining, agricultural or forestry applications within the District, including dozers, loaders, tractors, scrapers, graders, off-highway trucks, forklifts, and utility service vehicles. Not included are utility and lawn and garden equipment, off-road motorcycles, all-terrain vehicles, go-carts, golf carts, marine vessels, aircraft and locomotives.