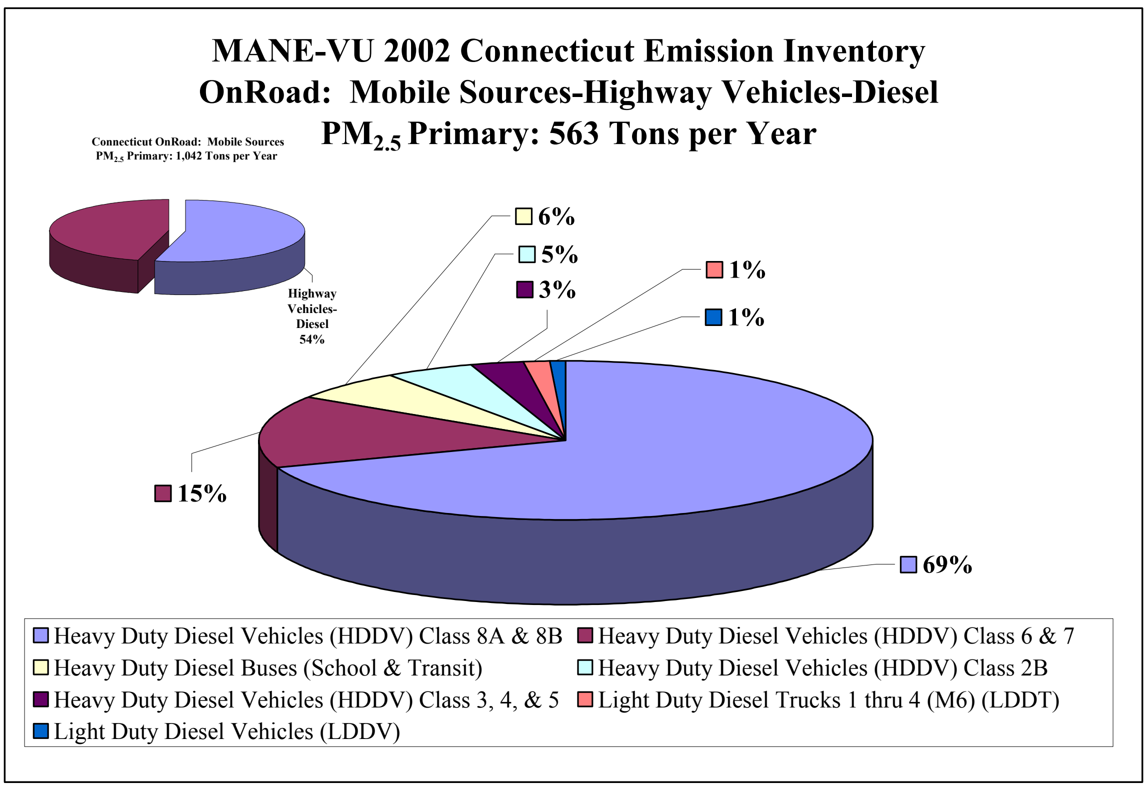
Special Act 05-07
Connecticut Clean Diesel Plan
Transit Sector Report

I. Introduction

Over 21,000 tons of fine particulate matter ($PM_{2.5}$) are emitted in Connecticut each year. These emissions come from a wide variety of sources including on-road and off-road diesel trucks and buses, the combustion of distillate oil and wood for heating, stationary engines, and portable engines. These sources also emit other pollutants that contribute to Connecticut's air quality problems. For example, on-road engines account for about 58 percent of the over 118,000 tons of nitrogen oxides (NO_X) emitted annually in Connecticut, off-road engines about 20 percent, with the remaining 22 percent from stationary and area sources.

Figure 1 represents the emissions of $PM_{2.5}$ from on-road diesel-powered vehicles in Connecticut in 2002. School and transit buses account for 6% of the total emissions of $PM_{2.5}$ or 33.78 tons per year. According to data from Connecticut Transit (CT Transit), transit buses subject to Special Act 05-07 (the Act) are responsible for 3.28 tons of particulate matter per year (or approximately 10% of the emissions from both transit and school buses). (See Table 3 on page 9.)

Figure 1[1]



[1] The Mid-Atlantic/Northeast Visibility Union (MANE-VU) was formed by the Mid-Atlantic and Northeastern states, tribes, and federal agencies in 2001 to coordinate regional haze planning activities for the region. MANE-VU provides technical assessments and assistance to its members.

The General Assembly has directed the Department of Environmental Protection (DEP), pursuant to the Act, to develop a Connecticut clean diesel plan to reduce the health risks from diesel pollution.

The DEP began the planning on July 19, 2005 with a kick-off meeting at the DEP's offices. As a result of this meeting, four subcommittees were formed to explore and develop recommendations for emission reduction strategies for the following sectors: on-road fleets, transit buses, school buses and off-road construction equipment. Each subcommittee included representatives of government, private industry, public health and the environmental sector. A set of action items was provided for consideration along with a directive to provide feedback to the DEP.

The requirements for the implementation strategy for transit buses, as set out in Section 1(b)(2) of the Act, are the most specific of the four sectors.[2] Vehicles covered by this section are publicly owned, not less than twenty-nine feet in length and have a model year of 2006 or earlier. The strategy should reduce emissions of diesel particulate matter by at least eighty-five percent no later than December 31, 2010. Diesel particulate filters (DPFs) are specifically mentioned as a control technology for implementation of this section, but alternative fuels and alternative engine technologies could be employed to reach the specified reductions.

The transit subcommittee was asked to examine the following issues:

- Statewide Baseline,
- Fleet Retrofit, Replacement Retirement Options,
- Clean Fuel Options,
- Anti-Idling,
- Leveraging Opportunities,
- Case Studies – Pilot Projects, and
- Other items Identified by the Group.

On August 17, 2005, the DEP hosted a Diesel Emissions Reduction Policy, Technology and Clean Fuels Forum. The forum was intended to inform the DEP's efforts to develop the Connecticut Clean Diesel Plan by providing experts on policy, control technology and clean fuels the opportunity to present information to all interested stakeholders. Much of the information received through this public input process is relevant to each of the four subcommittees and serves to inform several aspects of this report. The information from that meeting is distilled into a table detailing technology and clean fuel options, emission reduction benefits and cost. This table is reproduced in the Appendix to this report.

The Transit Subcommittee studied the reduction of diesel pollutants from publicly owned or funded motor buses[3] that have an engine model year of 2006 or older and are not less than twenty-nine feet in length. As specified in the Act, a strategy was developed to

[2] See Attachment A, Special Act 05-07, *An Act Establishing A Connecticut Clean Diesel Plan.*
[3] Motor Buses are specifically defined in section 14-1 (48) of the Connecticut General Statutes.

reduce diesel particulate emissions from transit buses by at least 85 percent, no later than December 31, 2010.[4]

Beginning with the 2007 model year (MY), all new heavy duty diesel engines will be required to meet federal emissions standards for particulate matter (PM) and nitrogen oxides (NO_X)[5] that are equivalent to or more stringent than the emissions reductions recommended in Special Act 05-07. Currently, the Connecticut Department of Transportation (DOT) and CT Transit have a policy in place that sets a 12-year turnover rate as a goal. If the State of Connecticut chose to mandate compliance with this policy and provided the corresponding funding, all transit vehicles would comply with the federal standard by 2019. The provisions in Special Act 05-07 move the compliance date forward to 2010. The transit sector report includes an evaluation of three options to consider as part of the State's diesel reduction efforts.

In developing these strategies, it is important to note that federal regulations mandating the use of ultra low sulfur diesel fuel (ULSD) and 2007 compliant engines will impose separate cost impacts on the transit industry nationwide. Transit operators in Connecticut will be impacted by these costs as well as by costs that may flow from implementation of the Act. Many of the assumptions made in generating the data sets compiled for this report are based on the fact that some costs and benefits would have accrued from the implementation of the federal regulations; every effort was made to isolate the data resulting from the state Clean Diesel Plan alone.

Before this strategy was developed, the Connecticut Region Council of Governments (CRCOG) had submitted a proposal for Federal Highway Administration (FHWA) funding under the Congestion Mitigation and Air Quality (CMAQ) program to retrofit the buses in CT Transit's Hartford-area and New Haven fleets. CRCOG had assembled a very detailed fleet inventory and a set of related data, which was made available to the transit subcommittee to use in completing its inventory. The database that had been compiled for the CMAQ application was expanded and a strategy to cover the entire Connecticut fleet was developed.

II. Transit Sector Report

A. Statewide Baseline

- The current inventory of transit buses in Connecticut is 658, of which it is projected that 487 transit buses will be subject to the Clean Diesel Plan by 2010.[6]

- Assumptions:

[4] Special Act 05-07 specifically identifies an 85% reduction target for diesel particulate matter, however DEP included reductions of other air pollutants such as oxides of nitrogen, carbon dioxide and toxics for consideration by the Committee. Air quality challenges such as ozone nonattainment and climate change require DEP to pursue a multi-pollutant reduction strategy to achieve progress in these areas.
[5] 40 CFR 86.007-11.
[6] See Attachment B.

- With an average turnover period of 12 years, buses from the 1997 MY and older will have been replaced by 2010 and are not included in the total.
- Beginning with the 2007 MY, federal regulations require that all manufacturers include emissions controls on their buses that will meet the requirements of the Act. Therefore, 2007 and later MYs are not included in the projected total for capital costs of transit buses impacted by the Act.
- 2007 and later MY buses are included in the projections of operating cost increases resulting from implementation of the Act.
- Buses that are retained as emergency backups would not be subject to the Act, provided that they meet certain standards for low annual mileage.

B. Fleet Retrofit, Replacement and Retirement Options:

Three options are presented for consideration by the subcommittee as avenues for meeting the goals and objectives specified in the Act. Option 1 is a strategy for installing DPFs on the Connecticut fleet by the end of 2010.

The second option relies on implementation of federal regulations that set emissions standards for all new heavy duty, onroad, diesel engines beginning with the 2007 MY and adherence to DOT's voluntary policy of a 12-year fleet replacement. The 2007 federal emissions standards for PM and NO_X are equivalent to or more stringent than the emissions reductions set out in the Act. Mandating the current fleet turnover rate of 12 years and providing the necessary funding will insure that all state transit vehicles would comply with the federal standard by 2019.

Option 3 assumes that CMAQ funding will be awarded to CRCOG to retrofit the Hartford-area and New Haven transit fleets with DPFs. With additional state funding, the remainder of the state fleet would be replaced with 2007 compliant buses at a mandatory turnover rate of 12 years.

- **Option 1: Installation of Diesel Particulate Filters**

  - **Background:**
    For the transit sector, the Act specifies an 85% reduction target for particulate matter; DPFs are one of the few technology options capable of achieving reductions in this range. DPFs are ceramic devices that collect the PM in the exhaust stream. The high temperature of the exhaust heats the ceramic structure and allows the particles inside to break down (or oxidize) into less harmful components. They can be installed on new and used buses, but must be used in conjunction with ULSD. The combination of DPFs and ULSD can reduce emissions of PM, hydrocarbons, and carbon monoxide by 60 to 90 percent.

    While there is some variation from manufacturer to manufacturer, most DPFs require that the engine temperature exceed 260° C for at least 40% of its duty cycle for effective operation. In many instances, diesel engines cannot achieve the requisite temperatures and other technology options must be considered.

In one of the first projects of its kind in the nation, CT Transit retrofitted 34 of the 55 transit buses in the Stamford fleet with DPF's and ULSD. This pilot project has provided CT Transit with much valuable information relevant to the implementation of the Act. For example, CT Transit has reported that DPF filters do not function adequately on Detroit Diesel Series 50 engines equipped with Exhaust Gas Recirculation (EGR).[7] There are approximately 191 transit buses equipped with this engine and EGR in the state. These are among the newest and lowest emitting buses in the transit fleet. If the technology does not become available by 2010, an alternative strategy would have to be developed to ensure that this portion of the fleet meets the specified reduction target.

DPFs must be periodically “regenerated” to remove the collected particulate matter. Special ovens are used to bake off the accumulated soot at high temperatures. DPFs can also incorporate passive regeneration techniques, such as the catalyzed particulate filter, or they can incorporate active regeneration techniques, such as the electrically regenerated particulate filter.

- **Assumptions:**
  - While other emissions control technologies are available, projections were made based on the installation of DPFs as specified in subsection (b)(2) of the Act.[8]
  - Effective DPF technology will be available for the Detroit Diesel 50 buses with EGR by 2010. If the technology does not become available, an alternative strategy would need to be developed to achieve the targeted reductions specified in the Act.
  - Buses will continue to be retired and replaced after 12 years.
  - There are 6 buses in the fleet that operate on #2 diesel fuel; in addition to the installation of the DPFs, the engine control module (ECM) computers on these buses will need to be reprogrammed to accommodate the ULSD fuel.
  - Buses that are retained as emergency backups should not be subject to this option; backup buses would be required to meet certain standards for low annual mileage that should be set out in legislation or regulations implementing the Act.
  - DOT and CT Transit will develop a proposed schedule of voluntary retrofit targets to implement Option 1 by 2010; this

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[7] According to CT Transit, Detroit Diesel is testing ways of overcoming this problem through re-programming engine controls and through modifications of filters. The manufacturer is responding to pressure from New York City transit operators to find a remedy quickly.
[8] See Attachment A.

would not be mandatory, but would serve to provide general goals for planning and reporting purposes.[9]

- **Capital Cost Projections**:
  - **Retrofit Costs:** The cost of retrofitting a bus with DPF includes the filter, a backpressure monitor to protect the engine and the installation. The cost for retrofitting 487 buses with DPF filters is estimated to be $3,993,400 ($7,500 per unit). Experience indicates that 15%, or 80 buses, will need unscheduled filter replacements for an additional cost of $536,000. Adding in $3,000 for reprogramming the ECM computers on 6 buses currently using #2 diesel fuel, the total cost for equipment purchase and installation is approximately $4,532,400.[10] (See Table 1.) It is assumed that all retrofit installations will be performed by CT Transit staff; therefore installation costs will be predictable and consistent.

Table 1: Estimate of Initial Cost to Retrofit Statewide Transit Fleet

9/4/2005

	Number	Filters* $6,000	Sensors $1,000	Installation $500	Inflation** $700	ECM $500	Total
Buses – existing buses 1997 or newer	363	$2,178,000	$363,000	$181,500	$254,100	-----	**$2,976,600**
Buses – buses on order for 2005 or 2006 (1)	124	$744,000	$124,000	$62,000	$86,800	-----	**$1,016,800**
Spare filters (15 percent)	80	$480,000	-----	-----	$56,000	-----	**$536,000**
Reprogram ECM computers for #2 diesel buses	6	-----	-----	-----	-----	$3,000	**$3,000**

Total buses to be retrofitted = 487 **TOTAL $4,532,400**

*Includes filters for buses with EGR (see text). A preliminary list of EGR buses is provided below.

CTTRANSIT Hartford = 63
CTTRANSIT New Haven = 84
SEAT Norwich = 5
GBTA Bridgeport = 34
Northeast Transit Waterbury = 5

**Prices are 2005 prices, but purchases will be staggered over 2006, 2007, 2008, and 2009. Assume an average of a $700 increase over all 4 years.

[9] A sample retrofit schedule would be: 20% of the eligible fleet in 2007, 20% in 2008, 30% in 2009 and 30% in 2010.
[10] Costs were derived by CT Transit based on experience with the Stamford fleet and manufacturers' projections.

  - **Bus Replacement Costs**: The capital cost of purchasing each 2007 MY bus will be approximately $14,500.00 greater than current replacement prices because emissions controls will be included on all buses manufactured for the 2007 MY and later. Therefore, the increased cost of replacing 171 pre-1997 MY buses due to be retired during the period covered by this legislation is estimated to be $2,479,500.00. While this is a result of federal regulations, not the state Clean Diesel Plan, it will be a significant extra burden on transit operators, impacting their ability to absorb the costs of the retrofits within their current capital budgets.
  - **Economies of Scale v. Inflation and Limits on Supply**: As manufacturers gear up to equip all new buses in the U.S. with DPFs to meet the 2007 federal standards, the costs of the filters may become less than current projections. Conversely, inflation and/or shortages in raw materials could result in increased prices. Cost projections in this report are reasonable estimates based on current information; they include inflation over the period covered by the legislation.

- **Operating Cost Projections**:
  - **Filter Maintenance**: DPFs require an annual cleaning at $500 per bus. More cost-effective methods of cleaning filters are currently under development. By the time the Clean Diesel Plan is fully implemented, the costs associated with annual filter cleaning may be lower than the projections.
  - **Filter Replacement**: After 5 years, filters must be replaced at a cost of $7,500 per bus. With retrofits projected to begin in 2006, the filter replacement costs will not come into the budget until 2011. With an estimate of 130 buses needing filter replacement per year, the annual operating costs for CT Transit would be increased by $975,000 upon full implementation. This leads to an overall annual cost increase of $1,300,000. (See Table 2.)
  - **Fuel Cost Differential**: DPFs require the use of ULSD, which is currently more costly ($0.12 per gallon) than the low sulfur diesel fuel. Federal law requires a changeover to ULSD in 2006 and the baseline cost is expected to change. While any resultant increase in fuel cost cannot be attributed to the state Clean Diesel Plan, it is noted as a potential financial burden that could impact the operators' ability to absorb the increased operating costs associated with the plan.

Table 2: Estimate of "Incremental" Operating & Maintenance Cost of Diesel Filters & ULSD

Statewide Transit Fleet

9/4/2005

Year	# Buses in fleet	Annual filter cleaning $500 = cost/bus		Filter Replacements (5 yrs) $7,500 = cost/bus		Total Annual Cost (2)
		# Buses w/filters	Cost	# Buses needing new filter (1)	Cost	
2007	650	200	$100,000	0	0	**$100,000**
2008	650	400	$200,000	0	0	**$200,000**
2009	650	650	$325,000	0	0	**$325,000**
2010	650	650	$325,000	0	0	**$325,000**
2011	650	650	$325,000	130	$975,000	**$1,300,000**
2012	650	650	$325,000	130	$975,000	**$1,300,000**
2013	650	650	$325,000	130	$975,000	**$1,300,000**

(1) Assume 1/5th of the fleet per year starting 5 years after the first retrofits.

(2) The incremental operating cost does not include the incremental cost of switching to ULSD fuel, since this is a federal requirement that all operators must comply with by September 2006. See text.

- **Emissions Reductions**:

  Using data from tests of New York City transit buses, CT Transit projected that implementation of the requirement for transit buses under the Act will result in a decrease of 87.8% or 2.88 tons of PM per year.[11]

  A significant portion, 29.4%, of the decrease in particulate emissions can be attributed to the changeover to ULSD alone.[12] This change is mandated by federal regulations and will occur beginning in June 2006 when those regulations take effect. Because DPFs cannot function without ULSD, emissions reductions are represented as resulting from the combination of ULSD and DPFs.

  Emissions reductions are summarized below in Table 3.[13] While DPFs and ULSD will decrease emissions of particulate matter, they do not decrease the production of NOx, a major ozone precursor. All of Connecticut has been designated nonattainment for the 8-hour ozone standard, and achieving additional reductions of NOx and VOCs are critical to solving Connecticut's attainment problem.

[11] See Attachment C.

[12] See Attachment D.

[13] DPFs reduce hydrocarbons (HC), a term sometimes used interchangeably with VOCs, and carbon monoxide (CO) as well as PM, but the Act is focused on PM.

Table 3: Estimated Emissions Reductions

Retrofitting Statewide Transit Bus Fleet with Diesel Particulate Filters (1)

9/4/2005

For Entire State Transit Bus Fleet	PM particulate matter	CO carbon monoxide	HC hydrocarbons
Baseline - LSF fuel & no filter (existing) (tons per year)	**3.28**	**32.98**	**3.63**
Clean Diesel Plan - ULSD fuel with filter (tons per year)	**0.40**	**2.00**	**0.25**
Emissions reduction (tons): **Annual**	**2.88**	**30.98**	**3.38**
Emissions reduction (%): **Annual**	**87.8%**	**93.9%**	**93.1%**
Emissions reduction (tons): **Project Life (2)**	**29.11**	**312.96**	**34.16**

Baseline 1 = existing condition with low sulfur diesel fuel and no filters

Clean Diesel Plan = All buses equipped with diesel particulate filters & operating on ULSD fuel

(1) Emissions estimates based on New York City tests.

(2) Project life varies by bus. It is based on emissions reductions achieved over the remaining life of a bus after it is retrofitted. Standard life expectancy of a new bus is 12 years. A 5-year old bus that is retrofitted has a remaining life (project life) of 7 years.

- **Cost Effectiveness**:

By dividing the increased annual operating cost of $1,300,000 from Table 2 by the annual PM reductions of 2.88 from Table 3, the annual cost will be $451,389 per ton of diesel particulates reduced from the transit bus sector when the Act is fully implemented in 2011.[14] Under the federal 2007 standards (and Option 2), this full annual cost would not be reached until 2019. The savings in health care costs resulting from the PM exposure should be weighed against the cost projections.

Diesel engines emit $PM_{2.5}$ which, when inhaled, can lodge deep in the lungs, aggravating existing heart and lung diseases to cause cardiovascular symptoms, arrhythmias, chronic obstructive pulmonary disease, heart attacks, asthma attacks and bronchitis. A 1999 report published in the *Journal of Transport Economics and Policy*[15] and

[14] The California Air Resources Board (CARB) used a similarly unweighted analysis in its 2002 Staff Report supporting implementation of its transit bus fleet retrofit program. That analysis used emissions estimates generated by a computer model as compared to the actual data used in this report. (See CARB report in Attachment E and CT Transit data in Attachment C.)

[15] McCubbin, Donald and Mark Delucchi , The Health Costs of Motor-Vehicle-Related Air Pollution, *Journal of Transport Economics and Policy,* September 1999, Vol. 33, Part 3, pp.253-86

referenced in a recent report for the CMAQ Program[16] states that the health costs resulting from exposure to $PM_{2.5}$ in urban areas range from \$14.81 to \$225.36 per kilogram. That would translate into an average health cost of \$109,000 per ton and is ten times more costly than NO_X at \$11,322 per ton.[17]

Transit bus emissions are unique in their public health impact because of the numbers of people directly exposed. According to DOT ridership figures, twenty-seven million Connecticut residents use 658 transit buses in the CT Transit system. Every passenger exiting from or waiting to board an idling bus inhales the pollutants from the diesel exhaust. And while a properly maintained bus with the windows closed will have few pollutants within the passenger compartment, there are obvious situations where passengers inside the bus are exposed to exhaust. In addition, emissions from city buses contribute to $PM_{2.5}$ hot spots and to the concentration of other pollutants affecting all urban residents. Investing in the reduction of emissions from transit buses will therefore have public health benefits that are amplified by the exposure factor.

Given these health concerns, the General Assembly could choose to pursue a funding mechanism to fully implement this section of the Act.

- **Option 2: Federal 2007 Diesel Program with Mandatory Fleet Turnover**:

In the absence of additional reduction strategies for transit buses, making CT Transit's current 12-year fleet turnover policy mandatory would insure that all transit buses would be compliant with the 2007 standards by 2019. The federal 2007 standards include reductions in NO_X, which are important for attainment of the 8-hour ozone standard. The identification of a funding mechanism to cover the costs of implementation would enhance the feasibility of this option.

Capital costs would include the differential between the retrofit option and the replacement of the entire fleet with 2007 compliant buses, effectively substituting replacement for retrofits. If each of the 487 buses subject to retrofits under Option 1 were to be replaced by 2007 compliant buses at an

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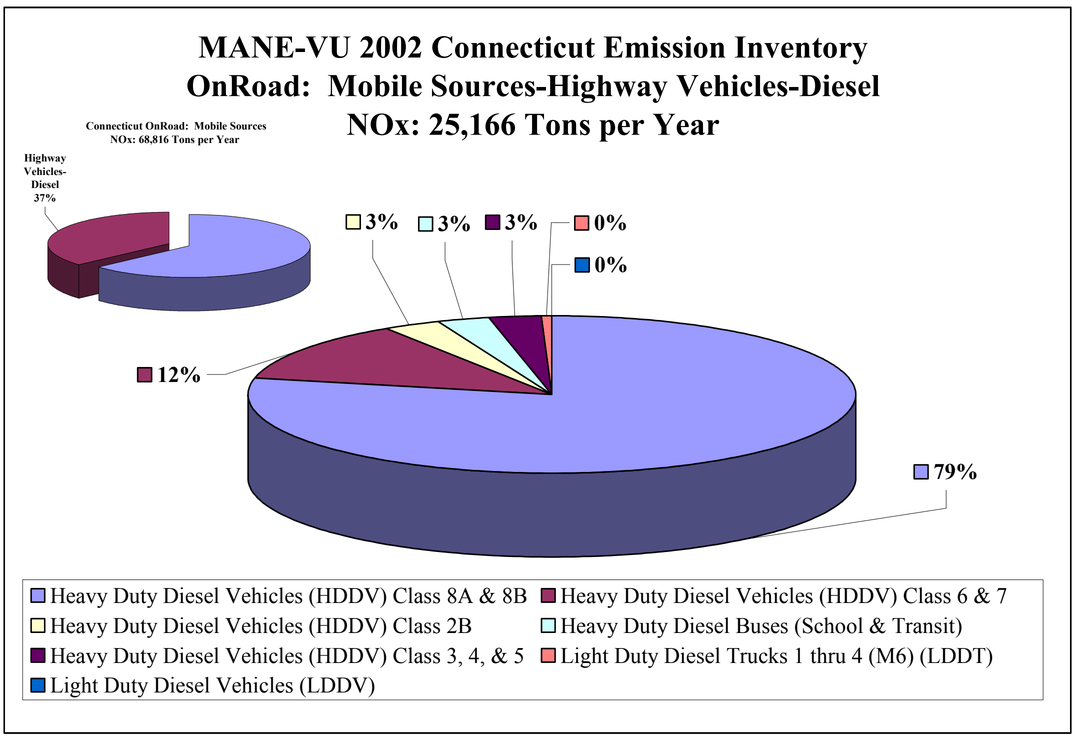
[16] Westcott, Robert F., Cleaning the Air: Comparing the Cost Effectiveness of Diesel Retrofits vs. Current CMAQ Projects, prepared for the Emission Control Technology Association, May 11, 2005. (See Attachment F.)

[17] The CMAQ report goes on to discuss weighting factors for various pollutants, noting that there is presently no weighting factor for $PM_{2.5}$. In generating a factor for its report, CMAQ assumed that the technology that removed PM would also remove NO_X. Since DPFs do not remove NO_X, that factor and its resultant product are not employed in this analysis. The generation of an appropriate weighting factor to use in this cost/benefit analysis is beyond the scope of this report.

increased cost of $14,500.00[18] per bus, the capital cost associated with that early fleet turnover would be increased by $7,061,500.00. Operating costs of the fully implemented program would be the same as for Option 1 starting in 2019 as opposed to 2011.

Because NO_X is also reduced in the 2007 compliant buses, the cost per ton of pollutants reduced will decrease as compared to the first option. According to Figure 2, school and transit buses account for approximately 755 tons of NO_X emissions per year. Using the 10% factor derived in the discussion of $PM_{2.5}$ emissions (see page 1), transit buses could be expected to contribute about 75 tons of NO_X per year. While 2007 technologies have not been fully developed and tested, it is apparent that even a 50% reduction in NO_X to meet the minimum standard for engines in 2007, added to the 2.88 tons of reduced $PM_{2.5}$, would result in a significant decrease in the annual cost per ton figure from $451,389 to $32,194.

Figure 2



This option provides public health benefits through the reduction of ozone-producing NO_X, but it extends the implementation period of public health risk from exposure to diesel particulates by nine years. The health-related costs stemming from this prolonged exposure should be taken into account when considering this option.

[18] Costs were derived by CT Transit based on experience with the Stamford fleet and manufacturers' projections.

As has been noted in the discussions of Option 1, the increased capital costs of the 2007 compliant buses ($14,500 per bus, $9,541,000 for the entire fleet of 658 buses) and the increased costs associated with operation and maintenance of the DPFs ($1,300,000 per year for the Connecticut fleet) are significant. Also, the increased cost of ULSD fuel (currently $0.12 per gallon, see Table 4) added to recent and dramatic increases in all fuel costs, will impose additional burdens on already stretched transit budgets that need to be addressed. If this option is to be selected and implemented, fully funding this option would be an important first step.

Table 4: Estimate of "Incremental" Cost of ULSD

Statewide Transit Fleet

9/4/2005

Year	# Buses in fleet	Fuel cost differential (1)	
		$0.12	= cost/gal
		# Gallons	Cost
2007	650	6,000,000	$720,000
2008	650	6,000,000	$720,000
2009	650	6,000,000	$720,000
2010	650	6,000,000	$720,000
2011	650	6,000,000	$720,000
2012	650	6,000,000	$720,000
2013	650	6,000,000	$720,000

(1) Current differential between regular diesel & ULSD is about 12 cents per gallon

- **Option 3**: **A Combination of Strategies**

  Option 3 entails: (1) awarding funds to CRCOG in response to its CMAQ application to retrofit the Hartford-area and New Haven fleets, (2) implementation of the federal 2007 standards, (3) mandating DOT's current 12-year turnover policy and (4) the potential identification of sufficient state funding to replace the remainder of the state transit fleet with 2007 compliant buses. This option will result in a more rapid reduction of $PM_{2.5}$ in Connecticut's urban centers, while furthering the reduction of ozone precursors in the state.

  CRCOG's application for CMAQ funds anticipates a total cost of $2,431,000 to retrofit the buses in the Hartford-area and New Haven transit fleets with DPFs; of that total, $486,200 must be provided by matching funds, consistent with requirements of the CMAQ program. Of the 487 buses subject to retrofits under the first option, 275 would be covered by the CMAQ grant.

Under this option, the remaining 212 buses would all be replaced by 2007 compliant buses as they reach a mandated turnover date at 12 years. At $14,500 per bus, the increased capital cost of replacing those buses would be $3,074,000.

The operating costs would be $1,300,000 upon full implementation in 2019, the same as those for the other options. PM emissions would be reduced from the entire fleet and NO_X would be reduced from the 212 buses replaced under this option. The cost effectiveness of Option 3, upon full implementation, becomes $67,692 per ton of pollutants reduced annually.

This option immediately helps to address the problem of PM hot spots in urban areas. The Hartford and New Haven fleets would be retrofitted promptly, thereby furthering environmental justice priorities.

New Haven and Hartford have 147 Detroit Diesel 50 buses with EGR. (See. Table 1.) These engines present the same technological issues raised under Option 1. It is assumed that an effective remedy will be developed that will allow these buses to function successfully with DPFs.

The increased capital costs of the 2007 compliant buses and the increased costs associated with operation and maintenance of the DPFs are, as previously noted, significant. Also, the increased cost of ULSD fuel added to recent and dramatic increases in all fuel costs, will impose additional burdens on already stretched transit budgets that need to be addressed. If Option 3 is to be selected and implemented, the General Assembly should be prepared to take steps to insure that this option is fully funded.

C. Other Clean Diesel Issues

In addition to the three options outlined above, DEP evaluated several other strategies. The following discussion highlights a series of low-cost recommendations.

- **Clean Fuels**:

Since DPFs and 2007 compliant buses require the use of ULSD fuel, other fuels were not evaluated in detail. Utilizing a blend of ULSD with up to 5% **biodiesel** in the transit fleet could improve the lubricity of the ULSD. Biodiesel is a renewable energy source that promotes energy independence. DOT can receive Energy Policy Act credit for utilizing biodiesel in the transit fleet.

Biodiesel is a cleaner-burning version of diesel fuel made from natural, renewable sources such as vegetable oils rather than petroleum. Biodiesel may be used as a blend fuel (as low as 5% to 20% biodiesel) or as a single neat fuel (100% biodiesel). Studies indicate that B100 and biodiesel blends generate less PM than conventional diesel (55% less PM from B100 and 18% less PM from B20), but more nitrogen oxides (6% more NOx with B100) than 100% petroleum diesel[19] and 2-3% more NOx with B20 (when engine tested by a dynamometer) than 100% petroleum diesel[20]. Recent tests by the National Renewable Energy Laboratory has shown a reduction in NOx when the entire vehicle was tested under a load. Because biodiesel contains no sulfur, however, vehicles powered by this fuel can use advanced aftermarket emission control devices to further reduce harmful emissions.[21]

Compressed Natural Gas (CNG) is a high-quality fuel that is a viable substitute for gasoline and diesel. Nearly 90% of the natural gas consumed in the US is from domestic sources, compared to less than 50% of the oil. Historically CNG, has been less costly than gasoline and diesel fuel on a per gallon equivalent basis nationwide. CNG are virtually toxic-free and emit significantly fewer pollutants than diesel vehicles: 40% to 86% less PM and 38% to 58% less NOx for heavy duty natural gas transit buses, school buses, refuse trucks and utility vehicles.

The major obstacles to the expanded use of CNG vehicles are their current higher cost compared to conventional diesel vehicles and the costs involved in establishing the infrastructure needed for refueling. Training and garage modifications to accommodate methane detection and ventilation systems may also be needed. Although these costs can be significant – for example the incremental cost of a CNG bus is approximately $25,000 to $40,000 more than a conventional diesel bus -- fleets can make a cost-effective transition to CNG by taking advantage of funding sources for alternative-fuel vehicle programs, such as Congestion Mitigation and Air Quality (CMAQ) grants, the US DOE State Energy Program (SEP) funds distributed through the national Clean Cities program, and federal and State tax incentives.[22]

- **Anti-Idling**:

Anti-idling programs provide a cost-effective and easy way to improve air quality and immediately reduce the exposure of people to the potential health impacts of diesel exhaust. Idling vehicles create emissions that contribute to smog and ground level ozone, and produce carbon dioxide (a greenhouse gas). Reducing diesel engine idling also saves money by conserving fuel and reducing wear and tear on engine parts. An idling long-haul tractor can consume 0.8-1.2 gallons of

[19] *Biodiesel, The Clean Green Fuel for Diesel Engines*, US Department of Energy, 2000, http://www.eere.energy.gov/cleancities/blends/pdfs/5450.pdf.
[20] *Biodiesel, The Clean Green Fuel for Diesel Engines*, US Department of Energy, 2000, http://www.eere.energy.gov/cleancities/blends/pdfs/5450.pdf.
[21] Source: Clean Cities Draft Memo dated November 17, 2005.
[22] Ibid.

fuel per hour; letting a vehicle idle for more than 10 seconds wastes more fuel than shutting it off and restarting it.

Transit buses that idle excessively when discharging or picking up passengers produce unnecessary pollution. Educating drivers and enforcing existing anti-idling regulations can increase the benefits resulting from improved emissions control technology under the Act.

Operators enforce state anti-idling regulations through driver education, frequent notices and random inspections.[23] DEP has developed signs that can be posted at bus stops to increase public awareness while reminding drivers of the anti-idling policy. As part of a continuing education package required for employment of licensure, transit bus drivers should review the operators' anti-idling policies as well as the state anti-idling regulations.

- **Funding:**
  - Transit formula funds, CMAQ funds and operating funds would all be available to assist in implementing the Clean Diesel Plan. However, CMAQ and other FHWA funds are well subscribed and shifting funds to pay for retrofits could mean less money for transit services.
  - Option 3 depends upon CMAQ funds to retrofit the Hartford and New Haven transit fleets.
  - An innovative solution would be to set up a state clean diesel fund, similar to the Carl Moyer Program in California.[24]

- **Relevant Case Studies and Pilot Projects**
  - Stamford, CT: Many projections of operating and maintenance costs have been based upon CT Transit's experience with its Stamford fleet, which has been operating successfully using DPFs and ULSD since the end of 2001. CT Transit's Stamford fleet was one of the first transit systems in the country to retrofit with DPFs; Region 1 EPA features this program on its website at: http://www.epa.gov/NE/eco/diesel/retrofit_projects.html.
  - New York City is required to retrofit its transit fleet under a state legislated plan similar to Connecticut's Clean Diesel Plan. The subcommittee received information about the problems with Detroit Diesel 50 engines with EGR technology based New York's experience. Information on this program is available at: http://www.mta.nyc.ny.us/nyct/facts/ffenvironment.htm - clean_bus.

III. Transit Subcommittee Recommendations

[23] See Attachments G, Regulations of Connecticut State Agencies, Sec. 22a-174-18(b) and H, Notice to CT Trans drivers dated July 21, 2005.
[24] See CARB Carl Moyer Clean Engine Incentive Program Fact Sheet, Attachment I.

DEP is recommending consideration of three options for reducing emissions of PM from the state's transit fleet by 85%, as set out in the Act. A set of other effective proposals for decreasing diesel particulate emissions is also included.

A. Option 1: Retrofits

- Retrofit 487 transit buses with DPFs by 2010.[25] Replace all 1998 MY and later buses with vehicles compliant with the 2007 federal standards.[26] The projected costs are summarized in Table 5 below.

Table 5: Implementation Costs for Special Act 05-07: Transit Option 1

Projected Capital Cost	$4,532,400
Projected Annual Operating and Maintenance Costs	$1,300,000
Cost Effectiveness for PM Reduction (per ton per year)	$451,389

- Clean Fuel: To take advantage of renewable fuel options, the feasibility and/or effectiveness of adding biodiesel to ULSD to improve lubricity should be further investigated.

B. Option 2: Federal 2007 Requirements with Mandatory Fleet Turnover:

- Mandate 12-year fleet turnover requirements to insure that all transit buses would be compliant with the 2007 standards by 2019; these buses would have emissions controls for NO_X, which are not addressed in the Act.[27]

- Elements of Option 2:
  - Fleet would achieve an 85% reduction in PM emissions by the later date of 2019.
  - The General Assembly should be aware that state funding to cover the increased capital and operating costs would enhance the feasibility of this option. (See Table 6.)
  - To take advantage of renewable fuel options, the feasibility and/or effectiveness of adding biodiesel to ULSD to improve lubricity should be further investigated.

[25] If the EGR technology for Detroit Diesel 50 buses cannot be modified to allow DPFs to function successfully, a strategy to address these buses should be developed and included in any legislation or regulations implementing the Act.
[26] Buses that are retained as emergency backups should not be subject to the Act. Backup buses would be required to meet certain standards for low annual mileage that should be set out in legislation or regulations implementing the Act.
[27] Buses that are retained as emergency backups should not be subject to the Act.

- The option would lead to some increased health costs resulting from exposure to diesel particulates during the extended implementation period from 2010 to 2019, but also to some benefits from the reduction of NO_X.

Table 6: Implementation Costs for Special Act 05-07: Transit Option 2

Projected Capital Cost Increase	$7,061,500
Projected Annual Operating and Maintenance Costs	$1,300,000
Cost Effectiveness to reduce PM and NO_X (per ton per year)	$32,194

C. Option 3: A Combination of Strategies:

Award CMAQ funds to CRCOG in response to its application to retrofit the New Haven and the Hartford area fleets.[28] Mandate a 12-year fleet turnover for the remaining buses in the Connecticut fleet to insure that they are compliant with the 2007 standards by 2019; these buses would have emissions controls for NO_X, which are not addressed in the Act.[29]

- **Elements of Option 3:**
  - CRCOG would receive $1,944,800 in CMAQ funding to retrofit the Hartford and New Haven fleets, matching it with $486,200.
  - Mandate a 12-year fleet turnover to insure that the remainder of the state fleet is in compliance by 2019.
  - The General Assembly should be aware that state funding to cover the increased capital and operating costs would enhance the feasibility of this option. (See Table 7.)
  - To take advantage of renewable fuel options, the feasibility and/or effectiveness of adding biodiesel to ULSD to improve lubricity should be further investigated.
  - Implementation of this option will alleviate of PM hot spots in Hartford and New Haven more rapidly. Some increased health costs could result from exposure to diesel particulates in smaller communities during the extended implementation period from 2010 to 2019. Option 3 also provides a significant and accelerated reduction in ozone-producing NO_X emissions in the state.

[28] See Footnote 21 regarding a strategy for the EGR technology for Detroit Diesel 50 buses.
[29] Buses that are retained as emergency backups should not be subject to the Act.

Table 7: Implementation Costs for Special Act 05-07: Transit Option

Projected Capital Cost Increase (including CMAQ match)	$3,560,200
Projected Annual Operating and Maintenance Costs	$1,300,000
Cost Effectiveness to reduce PM and NO_X (per ton per year)	$67,692

D. Other Recommendations:

- Anti-Idling: As part of a continuing education package required for employment and/or licensure, transit bus drivers should review the operators' anti-idling policies as well as the state anti-idling regulations.

- Funding:
    - CMAQ funding is being sought to retrofit the Hartford-area portion and could be sought for retrofitting the remainder of the CT Transit fleet.
    - State funding may be needed to assist in implementation of the Act in light of budgets strained by recent and dramatic increases in fuel costs and increased capital and operating cost burdens unrelated to the Act:
        - Federally mandated conversion to ULSD fuel
        - Capital cost of new buses meeting federal 2007 Standards
        - Increased operating costs related to DPF maintenance on 2007 compliant buses.
    - An innovative solution would be to set up a state clean diesel fund, similar to the Carl Moyer Program in California.[30]

IV. Conclusions

Concluding statement on how to move forward with the recommendations and options presented above.

[30] See Attachment H.

Attachment A

Senate Bill No. 920

Special Act No. 05-7

AN ACT ESTABLISHING A CONNECTICUT CLEAN DIESEL PLAN.

Be it enacted by the Senate and House of Representatives in General Assembly convened:

Section 1. (*Effective from passage*) (a) The Commissioner of Environmental Protection shall, in accordance with the provisions of this section, develop a Connecticut diesel emission reduction strategy.

(b) The Connecticut diesel emission reduction strategy shall recommend programs, policies and legislation for achieving reductions of diesel particulate matter consistent with reduction targets for diesel particulate matter indicated in the Connecticut Climate Change Action Plan 2005. The strategy shall provide the following:

(1) A description of the sources of diesel particulate matter emissions in the state and recommendations for maximizing diesel particulate matter emission reductions from identified sources;

(2) An implementation strategy, and an estimate regarding the cost and benefits to the state or municipalities of implementing such strategy, to reduce, not later than December 31, 2010, the level of diesel particulate matter emissions from motor buses, as defined in section 14-1 of the general statutes, that are publicly owned and funded, have an engine model year of 2006 or older, and are not less than twenty-nine feet in length, by (A) retrofitting the engines of such motor buses with diesel particulate filters in order to achieve a reduction of diesel particulate matter by not less than eighty-five per cent, or (B) using alternative fuels or alternative engine technology in order to achieve a reduction of diesel particulate matter by not less than eighty-five per cent;

(3) An implementation strategy, and an estimate regarding the cost and benefits to the state or municipalities of implementing such strategy, to maximize, not later than December 31, 2010, diesel particulate matter emission reductions from school buses and to prevent by said date diesel particulate matter engine emissions from entering the passenger cabin of the buses;

(4) An implementation strategy, to be phased in not later than July 1, 2006, on projects valued at more than five million dollars, to maximize particulate matter emissions reductions from construction equipment servicing state construction projects, and an estimate regarding the cost and benefits to the state or municipalities of implementing such strategy;

(5) Recommendations for technical assistance resources to be developed by the commissioner to support the implementation of diesel particulate matter reduction strategies by municipalities and other diesel fleet owners and operators;

(6) A strategy for securing and leveraging federal funds and funds from other sources to defray the costs of meeting the goals set forth in subdivisions (1) to (5), inclusive, of this subsection; and

(7) Recommendations for programs and policies to raise awareness about the health risks and climate impacts associated with diesel particulate matter pollution and the solutions available for reducing emissions of diesel particulate matter.

(c) In developing the report, the commissioner shall make draft recommendations available to the public on an Internet web site, provide opportunity for public comment, at times and locations to maximize public participation, and provide a forum for ongoing written public comment on the strategy.

(d) Not later than January 15, 2006, the commissioner shall submit, in accordance with the provisions of section 11-4a of the general statutes, a report containing the strategy to the joint standing committee of the General Assembly having cognizance of matters relating to the environment, and recommendations for legislation to implement such strategy. The strategy shall contain an addendum of all public comments received by the commissioner. The commissioner shall post a copy of the strategy and the addendum on an Internet web site.

Approved June 24, 2005

Attachment B
Inventory of Transit Buses: Model Year 1997 and Newer

Operator	City	Model Year	Existing or on order	Make & Model	# Buses	#2 diesel	# ECM reprog.
CT Transit	Hartford	2001	Existing	New Flyer D40LF	0		0
CT Transit	Hartford	2001	Existing	New Flyer - D40LF Leased	4		0
CT Transit	Hartford	2002	Existing	New Flyer D40LF	40		0
CT Transit	Hartford	2003	Existing	MCI Coaches	7		0
CT Transit	Hartford	2003	Existing	New Flyer D40LF	14		0
CT Transit	Hartford	2003	Existing	New Flyer Leased	6		0
CT Transit	Hartford	2004	Existing	New Flyer D40LF	42		0
CT Transit	New Haven	2003	Existing	New Flyer D40LF	42		0
CT Transit	New Haven	2004	Existing	New Flyer D40LF	42		0
CT Transit	Stamford	1999	Existing	El Dorado	13		0
CT Transit	Stamford	2001	Existing	New Flyer D40LF	32		0
CT Transit	Stamford	2002	Existing	New Flyer D40LF	0		0
CT Transit	Stamford	2003	Existing	New Flyer Hybrid	2		0
GBTA	Bridgeport	1998	Existing	Gillig Phantom 40ft	14		0
GBTA	Bridgeport	2003	Existing	New Flyer 40ft	13		0
GBTA	Bridgeport	2003	Existing	New Flyer 35ft	25		0
HART	Danbury	2001	Existing	Orion-V 35ft	10		0
HART	Danbury	2003	Existing	Trolley Thomas C150	1		0
HART	Danbury	2003	Existing	Orion VII 30ft	1		0
MDT	Middletown	2002	Existing	Gillig 30ft	4		0
MDT	Middletown	2002	Existing	International 30ft	2		0
MDT	Middletown	2003	Existing	Gillig 35ft	3		0
MLTD	Milford	1998	Existing	Thomas Citiliner	1		0
MLTD	Milford	2001	Existing	Thomas TL960 30ft	5		0
NBT	New Britain	1999	Existing	El Dorado 30ft	1	1	1
NETC		2003	Existing	New Flyer D40LF	5	1	5
NTD	Norwalk	1999	Existing	El Dorado 30ft	1		0
NTD	Norwalk	2002	Existing	Thomas SLF230 30ft	4		0
NTD	Norwalk	2003	Existing	Orion VII 35ft	19		0
NTD	Norwalk	2004	Existing	Gillig 29ft	3		0
SEAT	Norwich	2003	Existing	New Flyer 40ft	2		0
SEAT	Norwich	2003	Existing	New Flyer 35ft	3		0
SEAT	Norwich	2004	Existing	Gillig 30ft	2		0
				Subtotal A	**363**		**6**
SEAT	Norwich	2006	Order	not available	18		0
HART	Danbury	2006	Order	not available	10		0
WRTD	Windham	2006	Order	not available	2		0
NTD	Norwalk	2006	Order	not available	3		0
CT Transit	Hfd, NH, Stm	2005	Order	not available	48		0
CT Transit	Hfd, NH, Stm	2006	Order	not available	43		0
				Subtotal B	**124**		**0**
				Total retrofits needed	**487**		**6**

Attachment C

Calculation of Emissions Reductions: PM (particulate matter)

Bus Information *Hartford & New Haven Divisions*								Emissions rate *per mile*			Emissions			Savings due to filter & ULSF *Base 1 minus ALT*		
Operator	**City**	**# Buses**	**Model**	**Year**	**Bus Life Left** *years*	**VMT per bus** *daily*	**VMT** (daily)	**Base 1** fuel=LSD No filter *g/mile*	**Base 2** fuel=ULSD No filter *g/mile*	**ALT** fuel=ULSD **Add Filter** *g/mile*	**Base 1** fuel=LSD No filter *g/day*	**Base 2** fuel=ULSD No filter *g/day*	**ALT** fuel=ULSD **Add Filter** *g/day*	**daily savings** *grams*	**annual savings** *tons*	**lifetime savings** *tons*
CT Transit	Hartford	4	New Flyer - D40LF Leased	2001	8.00	85.0	340	*0.197	*0.139	*0.024	67	47	8	59	0.024	0.189
CT Transit	Hartford	40	New Flyer D40LF	2002	9.00	85.0	3,400	0.197	0.139	0.024	670	473	82	588	0.237	2.130
CT Transit	Hartford	7	MCI Coaches	2003	10.00	85.0	595	0.197	0.139	0.024	117	83	14	103	0.041	0.414
CT Transit	Hartford	14	New Flyer D40LF	2003	10.00	85.0	1,190	0.197	0.139	0.024	234	165	29	206	0.083	0.828
CT Transit	Hartford	6	New Flyer Leased	2003	10.00	85.0	510	0.197	0.139	0.024	100	71	12	88	0.035	0.355
CT Transit	Hartford	42	New Flyer D40LF	2004	11.00	85.0	3,570	0.197	0.139	0.024	703	496	86	618	0.248	2.733
CT Transit	New Haven	42	New Flyer D40LF	2003	10.00	85.0	3,570	0.197	0.139	0.024	703	496	86	618	0.248	2.485
CT Transit	New Haven	42	New Flyer D40LF	2004	11.00	85.0	3,570	0.197	0.139	0.024	703	496	86	618	0.248	2.733
CT Transit	Stamford	13	El Dorado	1999	6.00	85.0	1,105	0.197	0.139	0.024	218	154	27	191	0.077	0.461
CT Transit	Stamford	32	New Flyer D40LF	2001	8.00	85.0	2,720	0.197	0.139	0.024	536	378	65	471	0.189	1.515
CT Transit	Stamford	0	New Flyer D40LF	2002	9.00	85.0	0	0.197	0.139	0.024	0	0	0	0	0.000	0.000
CT Transit	Stamford	2	New Flyer Hybrid	2003	10.00	85.0	170	0.197	0.139	0.024	33	24	4	29	0.012	0.118
GBTA	Bridgeport	14	Gillig Phantom	1998	5.00	85.0	1,190	0.197	0.139	0.024	234	165	29	206	0.083	0.414
GBTA	Bridgeport	13	New Flyer 40ft	2003	10.00	85.0	1,105	0.197	0.139	0.024	218	154	27	191	0.077	0.769
GBTA	Bridgeport	25	New Flyer 35ft	2003	10.00	85.0	2,125	0.197	0.139	0.024	419	295	51	368	0.148	1.479
HART	Danbury	10	Orion-V 35ft	2001	8.00	85.0	850	0.197	0.139	0.024	167	118	20	147	0.059	0.473
HART	Danbury	1	Trolley Thomas	2003	10.00	85.0	85	0.197	0.139	0.024	17	12	2	15	0.006	0.059
HART	Danbury	1	Orion VII 30ft	2003	10.00	85.0	85	0.197	0.139	0.024	17	12	2	15	0.006	0.059

Attachment C

Calculation of Emissions Reductions: PM (particulate matter)

MDT	Middletown	4	Gillig 30ft	2002	9.00	85.0	340	0.197	0.139	0.024	67	47	8	59	0.024	0.213
MDT	Middletown	2	International 30ft	2002	9.00	85.0	170	0.197	0.139	0.024	33	24	4	29	0.012	0.106
MDT	Middletown	3	Gillig 35ft	2003	10.00	85.0	255	0.197	0.139	0.024	50	35	6	44	0.018	0.177
MLTD	Milford	1	Thomas Citiliner	1998	5.00	85.0	85	0.197	0.139	0.024	17	12	2	15	0.006	0.030
MLTD	Milford	5	Thomas TL960	2001	8.00	85.0	425	0.197	0.139	0.024	84	59	10	74	0.030	0.237
NBT	New Britain	1	El Dorado 30ft	1999	6.00	85.0	85	0.197	0.139	0.024	17	12	2	15	0.006	0.035
NETC		5	New Flyer D40LF	2003	10.00	85.0	425	0.197	0.139	0.024	84	59	10	74	0.030	0.296
NTD	Norwalk	1	El Dorado 30ft	1999	6.00	85.0	85	0.197	0.139	0.024	17	12	2	15	0.006	0.035
NTD	Norwalk	4	Thomas SLF230	2002	9.00	85.0	340	0.197	0.139	0.024	67	47	8	59	0.024	0.213
NTD	Norwalk	19	Orion VII 35ft	2003	10.00	85.0	1,615	0.197	0.139	0.024	318	224	39	279	0.112	1.124
NTD	Norwalk	3	Gillig 29ft	2004	11.00	85.0	255	0.197	0.139	0.024	50	35	6	44	0.018	0.195
SEAT	Norwich	2	New Flyer 40ft	2003	10.00	85.0	170	0.197	0.139	0.024	33	24	4	29	0.012	0.118
SEAT	Norwich	3	New Flyer 35ft	2003	10.00	85.0	255	0.197	0.139	0.024	50	35	6	44	0.018	0.177
SEAT	Norwich	2	Gillig 30ft	2004	11.00	85.0	170	0.197	0.139	0.024	33	24	4	29	0.012	0.130
SEAT	Norwich	18	not available	2006	12.00	85.0	1,530	0.197	0.139	0.024	301	213	37	265	0.106	1.278
HART	Danbury	10	not available	2006	12.00	85.0	850	0.197	0.139	0.024	167	118	20	147	0.059	0.710
WRTD	Windham	2	not available	2006	12.00	85.0	170	0.197	0.139	0.024	33	24	4	29	0.012	0.142
NTD	Norwalk	3	not available	2006	12.00	85.0	255	0.197	0.139	0.024	50	35	6	44	0.018	0.213
CT Transit	Hfd, NH, Stm	48	not available	2005	12.00	85.0	4,080	0.197	0.139	0.024	804	567	98	706	0.284	3.408
CT Transit	Hfd, NH, Stm	43	not available	2006	12.00	85.0	3,655	0.197	0.139	0.024	720	508	88	632	0.254	3.053
	Total Retrofits	**487**					**41,395**				8,155	5,754	993	7,161	**2.881**	**29.109**
	All buses	*487*					*41,395*	**Totals in tons/year =**			**3.281**	**2.315**	**0.400**	**2.881**		

**Emissions rates are based on NYC test of diesel particulate filters using Series 50 buses.*

Conversion factors:

907,194 = grams/ton

365 = days per year

Attachment D

Estimated Emissions Reductions (in tons)

Retrofitting Statewide Transit Bus Fleet with Diesel Particultate Filters

8-17-2005

	PM particulate matter	**CO** carbon monoxide	**HC** hydrocarbons
Baseline - LSF & no filter (existing)	**3.28**	**32.98**	**3.63**
Alternative 1 - ULSD & no filter	**2.32**	**23.48**	**0.80**
Alternative 2 - ULSD with filter	**0.40**	**2.00**	**0.25**

Emission reductions due to ULSD: - - -

Emissions reduction (tons): **Annual** *Baseline minus Alt 1*	**0.97**	**9.49**	**2.83**
% Emissions reduction: **annual** *Baseline minus Alt 1*	**29.4%**	**28.8%**	**78.0%**

Emission reductions due to Filter: - - -

Emissions reduction (tons): **Annual** *Alt 1 minus Alt 2*	**1.92**	**21.48**	**0.55**
% Emissions reduction: **annual** *Alt 1 minus Alt 2*	**82.7%**	**91.5%**	**68.8%**

Emission reductions due to ULSD plus Filter: - - -

Emissions reduction (tons): **Annual** *Baseline minus Alt 2*	**2.88**	**30.98**	**3.38**
% Emissions reduction: **annual** *Baseline minus Alt 2*	**87.8%**	**93.9%**	**93.1%**
Emissions reduction (tons): **Project Life** *Baseline minus Alt 2*	**29.11**	**312.96**	**34.16**

Baseline 1 = existing condition with low sulfur diesel fuel and no filters

Baseline 2 = in 2007 all bus fleets will have to use ultra low sulfur diesel fuel (ULSD)

Alternative = Adds diesel particulate filters, but also assumes we will be using ULSD fuel

Attachment E

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD (CARB)

STAFF REPORT: INITIAL STATEMENT OF REASONS

PROPOSED MODIFICATIONS TO THE PUBLIC TRANSIT BUS FLEET RULE AND INTERIM CERTIFICATION PROCEDURES FOR HYBRID-ELECTRIC URBAN TRANSIT BUSES

(Including Appendices E and F)

Report: http://www.arb.ca.gov/regact/bus02/isor.pdf
Appendix E: http://www.arb.ca.gov/regact/bus02/appe.pdf
Appendix F: http://www.arb.ca.gov/regact/bus02/appf.pdf

Attachment F

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

An Analysis Prepared for the Emission Control Technology Association

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

May 11, 2005

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

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

Executive Summary

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

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

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

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

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

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

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

Background

Cleaning the air to improve human health and lower medical costs has been an objective of U.S. government policy since at least the Clean Air Act of 1970. Concerns about poor air quality, especially in urban areas, led to the creation of the Congestion Mitigation and Air Quality (CMAQ) Program in 1990, which has set aside a portion of transportation monies for the past 15 years to fund innovative projects to reduce carbon monoxide, hydrocarbons, nitrous oxides, and smog in so-called non-attainment areas.[31] Vehicle emission inspection programs, high-occupancy vehicle (HOV) travel lanes, van pool programs, park-and-ride lots, and bike paths are examples of CMAQ projects.

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

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

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

The Health Costs of Air Pollution

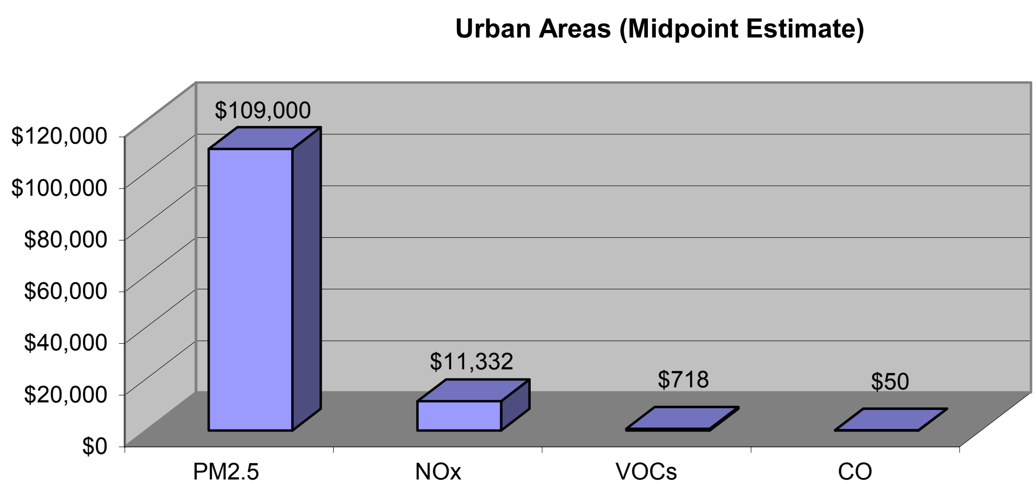
In the 1960s and 1970s the key health risks from air pollution were deemed to come from carbon monoxide, hydrocarbons (or volatile organic compounds, VOCs), nitrous oxides (NO_x), and smog, and early clean air legislation naturally targeted these pollutants.[32] During the past ten years or so, however, researchers have identified new pollutants from mobile sources that have particularly harmful health effects, especially in urban areas. Top concern today centers around particulate matter, and especially on fine particulate

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

matter. Fine particulates, with a diameter of less than 2.5 micrometers ($PM_{2.5}$), can get trapped in the lungs and can cause a variety of respiratory ailments similar to those caused by coal dust in coal miners. A significant portion of $PM_{2.5}$ emissions in urban areas come from off-road diesel equipment. According to analysis by the California Air Resources Board, on-road engines account for about 27% of PM emissions in California and off-road equipment is responsible for about 66% of PM emissions.[33]

Analysis by Donald McCubbin and Mark Delucchi published in the *Journal of Transport Economics and Policy* evaluates the health costs of a kilogram of various air pollutants, including CO, NO_x, $PM_{2.5}$, sulfur oxides (SO_x), and VOCs.[34] These researchers estimate health costs from such factors as, hospitalization, chronic illness, asthma attacks, and loss work days for the U.S. as a whole, for urban areas, and for the Los Angeles basin. For urban areas, they find the range of health costs per kilogram of CO was from \$0.01 to \$0.10, NO_x was from \$1.59 to \$23.34, $PM_{2.5}$ was from \$14.81 to \$225.36, SO_x was from \$9.62 to \$90.94, and VOCs was from \$0.13 to \$1.45. Taking the mid-points of these estimates, a kilogram of $PM_{2.5}$ therefore was nearly 10 times more costly from a health point of view than a kilogram of NO_x, more than 150 times more costly than a kilogram of VOCs, and more than 2000 times more costly than a kilogram of CO. On a per ton basis, a ton of $PM_{2.5}$ causes \$109,000 of health costs, a ton of NO_x costs \$11,332, a ton of VOCs costs \$718, and a ton of CO costs \$50 (Chart 1).

Chart 1



Source: McCubbin and Delucchi (1999)

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

Effectiveness of Diesel Retrofit Filters

Given the high health costs of $PM_{2.5}$, significant effort has gone into the development of technological solutions to deal with the problem. The best technologies involve the use of post-combustion filters with a catalyzing agent, which together trap and break down dangerous pollutants before they are emitted into the air. All new diesel trucks will be required to use these technologies by 2007 according to U.S. EPA rules, and off-road equipment will have to use these technologies by 2010. (Rules require 95% reductions in emissions of several pollutants, as well as a 97% cut in the sulfur levels in diesel fuel.)[35] However, given that the lifespan of a diesel engine can be 20-30 years, it will take decades to completely turn over America's diesel fleet. Therefore, by lowering emissions from older diesels, retrofits are an effective path to cleaner air over the next few decades.

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

Diesel particulate filters (DPFs), which generally cost $4,000-$7,000 per engine, are far more efficient. They are specifically targeted at keeping more dangerous PM out of the air than are DOCs. In fact, they can reduce $PM_{2.5}$ pollution from each vehicle by more than 90%, yielding an enormous cut in emissions over the life of the diesel engine, even when installed on newer, cleaner diesel vehicles. An additional requirement of DPFs, however, is that the vehicle must run on newer very low sulfur fuels. High sulfur fuel leads to sulfate emissions from the filter due to the very active catalysts needed to make the filters function properly. Thus, DPFs are most effective as a solution for vehicles in urban areas—such as construction equipment and urban fleets—where very low sulfur fuels are already available.[36]

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

The CMAQ Program

The CMAQ program is the only federally funded transportation program chiefly aimed at reducing air pollution.[37] Its historical purpose has been twofold: to reduce traffic congestion and to fund programs that clean up the air Americans breath. Within its air

[35] "EPA Dramatically Reduces Pollution from Heavy-Duty Trucks and Buses, Cuts Sulfur Levels in Diesel Fuel," *Environmental News*, EPA, 12/21/00

[36] Very low sulfur diesel fuel will be available nationwide by 2006.

[37] Transportation Research Board of the National Research Council: *The Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience* (2002) p.1.

quality mission, it is designed primarily to help non-attainment areas (mainly polluted urban zones) reach attainment for air quality standards under the Clean Air Act.[38] Historically many CMAQ projects have tried to change travel and traffic behavior in order to achieve its goals. These transportation control measures (TCMs) have been designed both to reduce traffic congestion as well as improve air quality. An example is a bicycle path. Designed to reduce the number of drivers on the road, bike paths could, in theory, achieve both goals. Further examples are vanpools, ridesharing and park and ride programs, and HOV lanes: all current CMAQ projects. Other projects have addressed emission reductions directly, as for example, through funding for state automobile emission inspection programs.

As a condition for reauthorizing the CMAQ program in 1998, the U.S. Congress required that a detailed 10-year assessment of the program be conducted. This review was performed by the Transportation Research Board of the National Research Council and was completed in 2002. This review found that CMAQ has been less than successful in reducing congestion and suggested that the most beneficial way for CMAQ to use its funds is to focus on air quality.[39] It also found that TCMs were less cost effective than measures to directly reduce emissions, such as through inspection programs.

Furthermore, the study suggested that CMAQ's focus within the domain of air quality is misplaced. CMAQ programs have targeted the gases considered the most dangerous pollutants for many years, like hydrocarbons, carbon monoxide, and nitrous oxides. While these gases pose recognized health and environmental risks, recent work has shown that the dangers of these substances pale in comparison to the danger of fine particulate matter.[40] In the words of the study, "Much remains to be done to reduce diesel emissions, especially particulates, and this could well become a more important focus area for the CMAQ program."[41] Further, discussing the fact that diesel-related CMAQ programs could be the most cost-effective, the study states, "had data been available on particulate reductions… the ranking of strategies focused on particulate emissions… would likely have shown more promising cost-effectiveness results."[42]

Comparing the Cost Effectiveness of Diesel Retrofits with Other CMAQ Projects

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

[38] ibid, p.1
[39] ibid, p.13
[40] ibid, p.13
[41] ibid, p.74
[42] ibid, p.131

estimates provide the comparison base. Published estimates for diesel retrofits are compared with these estimates.

As a first step in comparing the cost effectiveness of pollution reduction strategies, it must be noted that the CMAQ cost effectiveness estimates are presented as "cost per ton equivalent removed from air," with weights of 1 for VOCs, 4 for NO_x, but 0 for $PM_{2.5}$.[43] Relying upon the McCubbin and Delucchi health cost estimates, however, even weighted NO_x should be considered more damaging than VOCs. That is, even though 0.25 ton (the 1:4 ratio above) of NO_x removed counts as the CMAQ equivalent of one ton of pollution removed, it has a higher health cost than a ton of VOCs ($11,332 / 4 = $2,883 for NO_x vs. $718 for VOCs). As a second step, conservatively assume that all CMAQ projects remove the more damaging pollutant (NO_x). This still means that a ton of $PM_{2.5}$ reduction would be worth at least 9.45 tons of regular CMAQ reductions ($109,000 for $PM_{2.5}$ / $11,332 for NO_x).

Diesel retrofits are estimated to cost $50,460 per ton of $PM_{2.5}$ removed by the California Air Resources Board (CARB).[44] This estimate is very conservative and substantially higher than that cited by industry sources. Using the CARB cost estimate, diesel retrofits cost $5,340 per ton equivalent of air pollution removed ($50,460 / 9.45), based upon the CMAQ definition of ton equivalent and on the conservative assumption that CMAQ projects remove the most damaging pollutant reviewed. If a less conservative and more realistic assumption is used – that CMAQ projects remove a mix of NO_x and VOCs – then the cost-effectiveness of diesel retrofits becomes substantially more favorable, and could be as low as $332 per ton of CMAQ pollutant removed.

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

Other studies also conclude that diesel retrofits are highly cost effective compared with current CMAQ projects. The Diesel Technology Forum compared the benefits and costs of CMAQ projects with diesel retrofits for transit buses (for NO_x pollution reduction) and concluded that retrofits are a better use for CMAQ funds than any other typical CMAQ project, with the exception of inspection and maintenance programs and speed limit enforcement.[45] Also, the California EPA's Air Resources Board has estimated that diesel

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[43] Importantly, the study's $PM_{2.5}$ weight of 0 does not reflect $PM_{2.5}$'s health costs, but rather that fact that standards have not yet been set for it by the U.S. EPA. As the CMAQ 10-year review says, "$PM_{2.5}$ is generally regarded as the pollutant with the most pernicious health consequences, though to date standards have not been promulgated for its regulation for both measurement and economic reasons." (p. 295).
[44] California Air Resources Board, "Staff Analysis of PM Emission Reductions and Cost-Effectiveness," Sept. 6, 2002.
[45] "The Benefits of Diesel Retrofits," Diesel Technology Forum. See http://dieselforum.org/retrofit/why_ben.html.

retrofits have a benefit of between $10 and $20 for each $1 of cost.[46] And the U.S. EPA, in its justification for new on-road diesel rules in 2007 and off-road rules in 2010 estimates the benefits for diesel particulate filters at roughly $24 for each $1 of cost.[47]

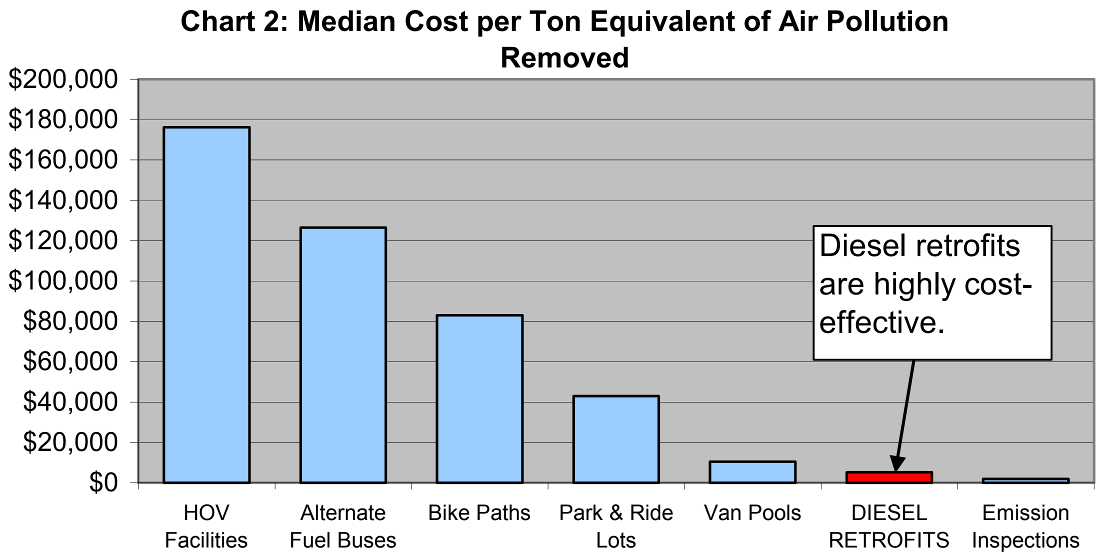
Table 1: Cost-Effectiveness of Current CMAQ Strategies
And Diesel Retrofits

(Median cost per ton equivalent of air pollution removed)

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

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

[46] "Perspectives on California's Diesel Retrofit Program," California EPA, Air Resources Board, presentation by C. Witherspoon, June 3, 2004.
[47] See, for example, "2007 Heavy-Duty Highway Final Rule," U.S. EPA, May 2000, which can be found at http://www.epa.gov/otaq/diesel.htm.



Conclusions

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

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

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

List of References

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Transportation Research Board of the National Resources Council, *The Congestion Mitigation and Air Quality Improvement Program: Assessing 10 Years of Experience*, 2002.

Witherspoon, C. "Perspectives on California's Diesel Retrofit Program," California EPA Air Resources Board, June 2004.

Attachment G

Regulations of Connecticut State Agencies

Section 22a-174-18. Control of particulate matter and visible emissions.

EFFECTIVE APRIL 1, 2004

(b) Visible emission standards.

(1) Stationary sources without opacity CEM equipment. Except as provided in subsection (j) of this section, an owner or operator of any stationary source without opacity CEM equipment for which opacity is measured using visual observation shall not exceed the following visible emissions limits:
  (A) Twenty percent (20%) opacity during any six-minute block average as measured by 40 CFR 60, Appendix A, Reference Method 9; or
  (B) Forty percent (40%) opacity as measured by 40 CFR 60, Appendix A, Reference Method 9, reduced to a one-minute block average.

(2) Stationary sources with opacity CEM equipment. Except as provided in subsection (j) of this section, an owner or operator of a stationary source for which opacity is measured using opacity CEM equipment shall not exceed the following visible emissions limits:
  (A) Twenty percent (20%) opacity during any six-minute block average; or
  (B) Forty percent (40%) opacity during any one-minute block average.

(3) Mobile sources. Except as provided in subsection (j) of this section, no person shall cause or allow:
  (A) Any visible emissions from a gasoline powered mobile source for longer than five (5) consecutive seconds;
  (B) Visible emissions from a diesel powered mobile source of a shade or density equal to or darker than twenty percent (20%) opacity for more than ten (10) consecutive seconds, during which time the maximum shade or density shall be no darker than forty percent (40%) opacity; or
  (C) A mobile source to operate for more than three (3) consecutive minutes when such mobile source is not in motion, except as follows:
    (i) When a mobile source is forced to remain motionless because of traffic conditions or mechanical difficulties over which the operator has no control,
    (ii) When it is necessary to operate defrosting, heating or cooling equipment to ensure the safety or health of the driver or passengers,
    (iii) When it is necessary to operate auxiliary equipment that is located in or on the mobile source to accomplish the intended use of the mobile source,
    (iv) To bring the mobile source to the manufacturer's recommended operating temperature,
    (v) When the outdoor temperature is below twenty degrees Fahrenheit (20 degrees F),
    (vi) When the mobile source is undergoing maintenance that requires such mobile source be operated for more than three (3) consecutive minutes, or
    (vii) When a mobile source is in queue to be inspected by U.S. military personnel prior to gaining access to a U.S. military installation.

Attachment H

NOTICE

No. 63-05

TO:	**All Operators**
FROM:	**Nick Mangene**
RE:	**Excessive Idling**
POSTING DATE:	**July 21, 2005**
EFFECTIVE DATE:	**In Effect**

I have just received a letter from the U.S. Environmental Protection Agency that basically serves as a forewarning that they in conjunction with the CDEP will be targeting bus systems in Connecticut to enforce the Connecticut anti-idling law. The campaign will focus on public buses because they often idle excessively in densely populated areas.

The letter also indicates that a similar campaign in Massachusetts cost the MBTA $328,000.00 in fines due to excessive idling violations. In addition, the MBTA was required to introduce a bus idling compliance plan and post signs reminding employees to turn off engines while idling.

In Connecticut, the engine idling rule is 3 minutes and there are *NO* exceptions to the rule.

In response to this forewarning, I am requiring dispatchers to make periodic radio announcements advising operators that their bus MUST be shut down at anytime they are stationary for more than 3 minutes. I am also requiring street supervisors to start a vigorous enforcement campaign. Again, there are NO exceptions to the rule and street supervisors will issue a violation to anyone who violates this rule.

Please refer to section 11.5 of your Employee Handbook for disciplinary penalties.

Remove date: Permanent

Attachment I

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY
AIR RESOURCES BOARD (CARB)

Fact Sheet on The Carl Moyer Clean Engine Incentive Program

http://www.arb.ca.gov/msprog/moyer/factsheet.pdf