Environment Canada

PROPOSED BUS ENGINE

REBUILD PROGRAM

A CANADIAN ALTERNATIVE

Submitted to:
Russell J. Robinson
Transportation Systems
Branch
Environment Canada

Submitted by:
Jack Patriarche MBA
P.Eng.
Patriarche & Associates

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EXECUTIVE SUMMARY

Environment Canada has commissioned this work in order to assess the introduction of a Bus Engine Rebuild Program, with similar effect to the one introduced by the US Environmental Protection Agency (EPA) in 1995.

The objective of the EPA program is to reduce emissions of particulate matter (PM). Generally, urban bus operators are required to rebuild engines to meet a PM standard of 0.10 g/bhp-hr, using a rebuild kit certified by EPA. If no such rebuild kit is available, the engine must be rebuilt using a kit certified to reduce PM emissions by at least 25%, relative to the engine's original level of PM emissions.

The EPA program, which was introduced in 1995, affects buses of model year 1993 and earlier. US transit agencies tend to retain their buses in service from 12 to 15 years, and the fleet has an average age of approximately eight years. In Canada, buses remain in service substantially longer; the current fleet has an average age of approximately 12 years. Recognizing the difference between the Canadian and US transit industries, one way for a program to be initiated would be for Environment Canada to sponsor a grant-based engine rebuild and replacement program targeted at buses in their peak use years. This would affect buses from model years 1979 to 1993, inclusive. It may also be practical, in certain instances, for transit agencies to voluntarily upgrade their equipment or for funding to come from other sources.

Older eligible buses (model years 1979 to 1985), which may be assumed to have received their final engine rebuild, would require $2,500 toward purchase and installation of a catalytic converter muffler. This is estimated to affect approximately 2,950 of Canada's 11,600 transit buses. This technology could reduce PM emissions by 223 kg per bus per year, also virtually halving hydrocarbon (HC) and carbon monoxide (CO) emissions.

Generally, the penetration of electronic engines is not as complete in the Canadian transit market as in the US. Buses with electronic engines in the 1986 to 1993 model years would require $2,500 toward the purchase and installation of an EPA certified kit that would achieve a PM standard of 0.10 g/bhp-hr. This is estimated to affect approximately 800 transit buses.

The remaining 3,200 transit buses in this age group would first have to be converted to electronic engine control. The electronic engine equivalents are no longer in production, so it is recommended that a re-powering program be put into effect. These buses would require $25,000 toward the purchase and installation of a new engine. The incremental cost of purchasing a new engine is increased by the need for substantial modifications to the bus and its powertrain, which are partially offset by fuel savings. The estimated reduction in PM emissions is approximately 600 kg per bus per year, with additional reductions in HC, CO, and oxides of nitrogen (NO_x). The fuel economy savings, over 25,000 L per year per bus, would reduce greenhouse gas emissions by 71,000 kg.

In total, a program could affect approximately 7,000 buses in Canada. The program would be in effect from July 1, 2000 to March 31, 2008, and would cost a total of $91 million.

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ENVIRONMENT CANADA BUS ENGINE REBUILD PROGRAM

1. INTRODUCTION

Environment Canada is considering the introduction of a Bus Engine Rebuild Program, similar in focus to the one introduced by the Environmental Protection Agency (EPA) in the US in 1995. Patriarche & Associates were contracted to review the EPA program, analyse what aspects have been more (or less) successful, and suggest what a Canadian program might look like. Other factors for consideration were the provincial role in such a program, and the potential to include an apprenticeship component in bus engine rebuilding.

One of the keys in reviewing the program is contact with engine and rebuild kit manufacturers to determine the availability of kits in future years. In addition, the Canadian Urban Transit Association (CUTA) was expected to provide substantive information regarding transit agencies, bus population, and engine families.

Much of the research was conducted on the Internet and through telephone contact. One trip to Washington DC was made to consult directly with EPA staff and with the American Public Transit Association (APTA). Both program staff and enforcement staff at EPA were consulted. A list of contacts is included as Appendix A, and a list or references is included as Appendix B. The California Air Resources Board was also consulted through their web site and by e-mail to seek information on their programs.

This report includes a summary of the EPA program, including information on its costs and effects, in Section 2. Section 3 discusses the size, age, activity, and regional distribution of the Canadian transit industry. Section 4 presents a potential structure for a Canadian program, with the costs and benefits of the potential program discussed in Section 5. The provincial role is discussed briefly in Section 6. Section 7 reviews labour issues, including the potential for an apprenticeship program. In Section 8, implementation issues such as timing and duration are discussed. Section 9 comprises the conclusions and recommendations.

2. OVERVIEW OF EPA URBAN BUS RETROFIT/REBUILD PROGRAM

2.1. Program History

The regulatory authority for the program is the Clean Air Act, and particularly the Clean Air Act Amendments of 1990. Section 219 (d) requires the EPA to control emissions from pre 1994 urban buses that have had the engine replaced or rebuilt after January 1, 1995. The regulations are limited to pre~1994 urban buses operating in Metropolitan Statistical Areas (MSAs) and Consolidated Metropolitan Statistical Areas (CMSAs) with a 1980 population of750,000 or more.[1] Some of these CMSAs may incorporate several transit operators, all of which fall into the program. EPA estimates the program covers about 35,000 of the 72,000 buses currently in service in the USA.

A Notice of Proposed Rule Making (NPRM) was issued on September 24,1991. This generated comments from the transit industry, engine and component manufacturers, and other interested stakeholders, which were compiled and synthesized prior to issuing a second request for comments on a revised program in 1992.[2] The EPA conducted further analysis of the second round of comments[3] prior to issuing the Final Rule on April 21, 1993. There have been several amendments and clarifications since.

The initial specifications for the program were drawn up by staff of the Office of Mobile Sources, based in Ann Arbor. This is a separate group from the one now administering the program.[4]

2.2. Program Provisions

The objective of the program is to reduce emissions of particulate matter (PM). The EPA requires that actions taken to reduce PM emissions cannot lead to a substantial degradation in control of other emissions.[5]

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[1] Environmental Protection Agency. *Final Regulatory Support Document and Summary and Analysis of Comments: urban Bus Retrofit/Rebuild Program.* March 1993
[2] Environmental Protection Agency. *Supplementary Information - EPA Proposal for an Urban Bus Retrofit/Rebuild Program*. July 1992
[3] Environmental Protection Agency. *Final Regulatory Support Document and Summary and Analysis of Comments: Urban Bus Retrofit/Rebuild Program.* March 1993
[4] Interview with Anthony Erb, Bill Rutledge, Office of Mobile Sources, EPA. In an interview with Jerry Trotter and Frank Cihak, APTA, it was mentioned that the individuals first involved with the program had more experience with light duty vehicle programs than with heavy duty vehicle programs. It was noted that the purchasing, specifying, and rebuilding processes are quite different for heavy duty vehicles.
[5] Interview with Anthony Erb, Bill Rutledge, Office of Mobile Sources, EPA.

The EPA Program permits a transit agency to select one of two program Options. In the first, an engine-based standard is applied; in the second, a fleet average is calculated. A transit agency may elect to switch from one option to another, if currently in compliance but may not subsequently switch hack to its previous program option.

Under Option 1, urban bus operators are required to rebuild engines to meet a PM standard of0.l0 g/bhp-hr. If no rebuild kit has been certified by EPA to meet that standard, with a life cycle cost of $7,940 or less (1992 dollars), the engine must be rebuilt using a kit that reduces PM emissions by at least 250/0, relative to the engine's original level of PM emissions. If no kit has been certified by EPA to meet that 25% standard at a life cycle cost of $2,000 or less (1992 dollars), the engine is to be rebuilt to its original standard or better (for PM emissions).[6] The Final Rule lays down very specifically what is meant by “life cycle cost”, and specifies how to calculate incremental costs such as additional fuel cost (savings), incremental maintenance cost, etc.

EPA certifies the kits, based on the manufacturers' claims of performance. Manufacturers are required to test the kits according to the transient Federal Test Procedure[7] for heavy duty vehicles, and to provide emission results showing that the kit not only meets the PM standard, but also that the other regulated emissions are within the relevant standards. The ability to meet the cost limits is also a part of the certification. Kits may be tested on a new or used engine. Kits may not interfere with any onboard diagnostic equipment, nor may they cause degradation of bus performance.

Kit manufacturers notify EPA of their intent to seek certification, and then supply data to support the claim. These data are circulated for public comment via the Federal Register, after which questions and comments are referred to the manufacturer for rebuttal. If approved, the announcement is made via the Federal Register. This process can take up to two years.[8]

The manufacturers are required to warrant the kits against defects for 100,000 miles, and for emissions performance for 150,000 miles, without time limit. There is currently no audit of the kit manufacturers, and no in-use testing, neither is there any durability testing. There is provision for

[6] Final Rule: Retrofit/Rebuild Requirements for 1993 and earlier Model Year Urban Buses, Federal Register, Volume 58, No. 75 April 21, 1993.
[7] There is some flexibility whether manufacturers wish to use a chassis dynamometer or engine dynamometer test.
[8] Kit manufacturers believe that the process is unduly time consuming and is open to competitive gamesmanship as other equipment manufacturers seek to delay or derail the competitor’s kit. EPA indicated that one recent innovation is providing manufacturers a letter of approval, which allows marketing to begin prior to the final announcement in the Federal Register, saving perhaps three to four months.

de certification.

There is also a provision for engine replacement. A credit of $10,000 is allowed under the program for installing a new, unused engine, meeting the same requirements for PM emissions performance (i.e. must get to 0. TO g/bhp-hr, or reduce PNI emissions by 25% if no engine at the 0.10 level is available). The $10,000 credit becomes part or the life cycle cost calculation, and so is in 1992 dollars.

Under Option 2, the transit operator must meet an annual average fleet PM level. This requires reduction of PM emissions from affected urban buses (pre-1994 model year) to a level that is low enough to meet an annual average target level for the fleet (TLF), which is calculated for each year of the program beginning in 1996. The Final Rule contains explicit instructions regarding calculation of the fleet's TLF, and also a table specifying the pre- and post-rebuild PM emissions to be attributed to each engine model and model year.[9] The EPA also provides a spreadsheet to facilitate the calculations.

Enforcement (for both options) is by audit on site, conducted by E15A's Office of Enforcement and Compliance Assurance. The audit is essentially a paper trail review, with some "under the hood" inspection but no tests (either chassis or engine dynamometer). These audits are samples of both buses and flies, rather than a complete fleet review. The penalty for violation of the program is up to $25,000 per engine.

While the inspections have turned up the occasional wrong part, they have resulted in few prosecutions. Out of 12 audits, 7 operators were found to be in violation. Most violations were attributed to teething problems in a new program; three resulted in modest fines, but nowhere near the $25,000 per engine maximum penalty. The first one believed to warrant prosecution is in progress now.[10]

Kits are required to be identified as an EPA certified kit (and to which standard), and are to carry a serial number. Each certified kit must have a record of the parts numbers contained in the kit.[11]

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[9] Final Rule: Retrofit/Rebuild Requirements for 1993 and earlier Model Year Urban Buses. Federal Register, Volume 58, No. 75 April 21, 1993. The EPA produces a spreadsheet to assist transit operators in calculating their TLF. Both EPA and APTA staff commented on the complexity of the fleet averaging option; very few fleets have elected to pursue Option 2.
[10] Interview with David Alexander, Office of Enforcement and Compliance Assurance, EPA.
[11] Another issue that has arisen during audit is that the requirement is for a serial number, not for a unique serial number. Occurrences have been found of duplicate serial numbers, according to Mr. Alexander.

2.3. Program Resources

When EPA began their program, they were budgeted at 2.5 Person Years (PY). They are now down to 1.25-1.5 PY, plus roughly 0.25 PY of management time. They estimate spending of $2Q000 on communications activities (mostly through the Federal Register) plus a further $4,000 of travel budget, per year. [12]

On the enforcement side, quantification of the resources applied to the program is more difficult. Twelve audits have been completed over the life of the program to date, mostly in 1997 with only one last year. [13] Each audit takes two senior staff (one lawyer from the Office of Enforcement and Compliance Assurance and one program manager from the Office of Mobile Sources), and one or two support staff. The EPA regional offices provide the support staff. For a small agency of under 200 buses, it was estimated that an audit would take 0.5 day; for a large one (e.g. Boston, which ranks in the top five US transit agencies), it could take up to three days. [14]

While there is no requirement for notice, EPA typically allows up to three weeks advance warning of an impending audit to enable the assembly of the relevant records. They also indicate what information will be required.

2.4. Program Results

The program covers 49 MSAs and CMSAs, which embrace an estimated 80% of the urban bus population. Using APTA's 1991 Transit Passenger Vehicle Fleet Inventory, EPA identified a total population of about 55,000 buses and vans in the 1990 fleet, of which 44,000 qualified as urban buses under the definition of the program. 80% of that number represents a target population of 35,200 buses in 1990. [15]

EPA estimated an average life of 15 years for an urban bus, and assumed that the population was

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[12] Interview with Anthony Erb and bill Rutledge, Office of Mobile Sources, EPA. This represents the EAP Headquarters Budget; the program also draws to some extent on regional offices and their staff resources.
[13] 1998 was an anomaly; the legal staff attached to the program were diverted to a prosecution of heavy engine manufacturers unrelated to the Urban Bus Engine Retrofit/Rebuild Program.
[14] Interview with David Alexander, Office of Enforcement and Compliance Assurance, EPA.
[15] Environmental Protection Agency. *Final Regulatory Support Document and Summary and Analysis of Comments: Urban Bus Retrofit/Rebuild Program.* March 1993.

evenly distributed among model years. This translates to a replacement level of approximately 2,350 buses per year. EPA also estimates that engines are rebuilt every four years, a maximum of three times.

EPA also assumes no degradation of PM emission performance over time in service, and so used certification levels of PM for the calculations of program impact. For engines ofpre 1988 vintage, EPA based the estimated emission level on discussions with engine manufacturers and other test data.

During engine certification, emissions measurements are taken over the heavy duty transient test cycle and are determined in g/bhp-hr. EPA converts these figures to g/mile, using a conversion factor of 7.9 developed especially for an urban bus duty cycle.[16] Appendix C presents a breakdown of engine models and PM emissions by model year.

EPA developed an equation that calculates the PM emissions for a bus for any year of its 15 year useful life:

(PM level (g/bhp-hr) x 7.9 x annual miles)/1 OOQ = annual PNI (kg)

EPA's estimate of the program benefits is shown in Table 1 below.

TABLE 1 - ANNUAL PARTICULATE EMISSION INVENTORY FROM 1993 AND EARLIER MODEL YEAR URBAN BUSES UNDER RETROFIT/REBUILD PROGRAM[17]

Calendar Year	Baseline Inventory (tonnes)	Retrofit Inventory (tonnes)	Difference (tonnes)	Difference (%)
1995	**3372**	**3372**	**0**	**0%**
1996	**2992**	**2864**	**128**	**4%**
1997	**2629**	**2446**	**183**	**7%**
1998	**2285**	**1894**	**391**	**17%**
1999	**1960**	**329**	**631**	**32%**
2000	**1652**	**852**	**800**	**48%**

[16] *Development of Conversion Factors for Heavy-Duty Bus Engines.* EPA Technical Report EPA-AA-RDSD-EVRB-92-01. July 1992. Cited in Environmental Protection Agency. *Final Regulatory Support Document and Summary and Analysis of Comments: Urban Bus Retrofit/Rebuild Program.* March 1993.

[17] Environmental Protection Agency. *Final Regulatory Support Document and Summary and Analysis of Comments: Urban Bus Retrofit/Rebuild Program.* March 1993.

2001	**1356**	**660**	**696**	**51%**
2002	**1085**	**464**	**621**	**57%**
2003	**859**	**287**	**572**	**67%**
2004	**661**	**233**	**428**	**65%**
2005	**488**	**186**	**302**	**62%**
2006	**326**	**140**	**186**	**57%**
2007	**163**	**93**	**70**	**43%**
2008	**47**	**47**	**0**	**0%**
2009	**0**	**0**	**0**	

The table above assumes that all 1988 and later model year engines will meet the 0.10 g/bhp-hr rebuild standard. The PM benefit peaks at 800 tonnes in 2000. and declines thereafter as the older buses are retired, until 2008 when the program will have run its course. Even during the years of applicability, there is some decline in the per-bus benefit; older buses are generally used less, and the EPA depreciated annual mile>: traveled at 7% per year to reflect this reality.

Over the full lifetime of the program, EPA estimates a total of 3,300 tonnes of PM emissions (on a discounted basis). Based on an assumed mix of particulate traps and rebuild kits, assuming that fuel economy could decrease by 2% in the presence of a trap, and assuming that diesel fuel will increase in price at 3% per year, EPA calculated a total cost over the life of the program of $93 million. The yearly costs were discounted to 1995 at a rate of 7%.

EPA has estimated a total discounted cost effectiveness of $25,500/tonne of PM for the program.

2.5 Industry Reaction

Industry reaction to the Urban Bus Retrofit/Rebuild Program has been cautiously positive. While the transit agencies are generally very willing to take on initiatives that present themselves in a positive environmental light, they face fairly restrictive financial realities. EPA did not offer any additional funding to complement the introduction of the program.[18]

Transit in the US receives a substantial amount of capital funding from the federal Transit Agency (FTA). However, this has declined from close to $8 billion in 1981 to about $4 billion in 1996 (T995 dollars). Overall, transit agencies covered operating costs in 1995 with the help of subsidies from the federal government (4.2%), from state government (2T.6%), and from local government (22.0%). The farebox contributed 38.9% of operating costs, with 13.4% from other sources such as local

[18] Environmental Protection Agency. *Final Regulatory Support Document and Summary and Analysis of Comments: Urban Bus Retrofit/Rebuild Program.* March 1993.

gasoline taxes dedicated to transit funding.[19]

The introduction of the Urban Bus Engine Retrofit/Rebuild Program put a significant strain on the transit agencies' declining financial resources. Nevertheless, they seem to have found a way to absorb the cost of the program and are implementing it.

The engine manufacturers are also supportive. Detroit Diesel, for example, has a policy of replacing older engine parts with the current equivalent, where feasible. However, they have reservations about other kit manufacturers going beyond aftertreatment; for example, a number of aftermarket suppliers (e.g. Engelhard, Johnson-Matthey), known more for their aftertreatment products, also supply kits that include some internal engine parts.[20]

3. THE CANADIAN TRANSIT MARKET

3.1. Transit Funding

Transit funding is every hit as much an issue in Canada as in the US, and perhaps more so. While many provinces used to have substantive transit subsidy programs in place, these have been virtually eliminated to the point where transit funding is essentially a local responsibility. To impose a substantial additional cost (through requiring more expensive rebuilds)[21] would risk fare increases that might adversely affect modal split; fewer transit riders and more single occupant cars would be counterproductive in emissions performance.

3.2. The Canadian Transit Population

There are approximately 117 transit agencies in Canada. As Table 2 shows, almost half operate fewer than 20 buses.

TABLE 2 - DISTRIBUTION OF TRANSIT AGENCIES BY PROVINCE AND SIZE[22]

Province	Number of Buses in Service (1998)						
	1-19	20-39	40-59	60-100	101-200	201-400	401-600>600

[19] American Public Transit Association. Transit Fact Book, 5Y" Edition. January 1999.
[20] Engine manufacturers are not enthusiastic about other companies “tampering” with the internal parts of their engines, being concerned that a lack of understanding of engine dynamics could lead to problems in other parts of the engine and drivetrain. See Appendix F for EPA certified kits.
[21] For example, installing a catalytic converter muffler imposes an additional cost of approximately US$2000 per bus.
[22] Canadian Transit Heritage Foundation. *The Street Side Guide to urban Transit Fleets in Canada. 1998 Edition.* August 1998

Yukon	I	0	0	0	0	0	0	0
British Columbia	21	4		0	I	0	0	
Alberta	2	5	0	0	0	0	0	2
Saskatchewan	I	0	0	I	I	0	0	0
Manitoba	I	0	0	0	0	0	I	0
Ontario	25	16	7	2	3	I	0	2
Quebec	0	I	0	2	I	2	I	
NewBrunswick	0	2	I	0	0	0	0	0
NovaScotia	3	I	0	0	I	0	0	0
Newfoundland	I	0	I	0	0	0	0	0
CANADA	55	29	10	5	7	3	2	6

Canadian fleets are holding their buses in service longer and longer. In the US, federal funding is geared to a 12 year replacement cycle and transit agencies generally retire vehicles at between 12 and 15 years. [23] Canadian transit fleets, in contrast, tend to hold their vehicles for 18 or more years. [24] An emerging trend is for transit fleets to buy old US buses and rebuild them at substantial costs and then run them for up to ten more years. [25]

Table 3 shows the age distribution of the Canadian fleet (the oldest model year still in service is 1960 - five buses operating in Winnipeg, MB).

TABLE 3 - AGE DISTRIBUTION OF CANADIAN TRANSIT BUSES [26]

Model Year	Number of Buses	Percentage
pre 1980	**2066**	**18%**
I980-84	**2207**	**19%**
1985-89	**2212**	**19%**
1990-94	**2907**	**25%**
1995-98	**2211**	**19%**
Total Fleet	**11603**	

While data are available regarding the numbers and model years of buses, there are no data available describing the engines powering those buses. The predominant engine in Canada is reported to be the naturally aspirated DDC 6V71. Cummins - particularly its L-10 - also holds a

[23] Interview with APTA staff and engine manufacturers.
[24] Interview with Mark Johnston, Detroit Diesel. With no outside funding in most provinces, there is no incentive to replace a bus as long as it continues to operate and maintenance costs less than purchase or lease.
[25] Interview with Kevin Brown, Engine Control Systems.
[26] Canadian Transit Heritage Foundation. *The Street Side Guide to Urban Transit Fleets in Canada. 1998 Edition.* August 1998.

significant share of 15 - 20%, and there are some other engine types. There arc also pockets of DDC 6V92 engines. which was believed to be the dominant choice in model years between 1989 and 1993. The DDC Series 50 (four-stroke) was introduced in 1993, and is believed to hold the largest marker share in new buses since that year again with equivalent Cummins products such as the ISM-280 continuing to capture 15 - 20%. Our estimate of the engine families for pre-1993 model years is shown in Table 4. [27]

[27] Based on discussions with DDC, Cummins, and Engine Control Systems.

TABLE 4 - ENGINES AND EMISSIONS

Model Year Buses/Engines	Engine Model	% of Affected Population	Pre-Rebuild PM Level (g/bhp-hr)[28]	Number of
1993	DDC 6V92TA DDEC II	85%	0.10	210
	Cummins L-I0 EC	15%	0.10	37
1992	DDC 6V92TA DDEC II	85%	0.25	417
	Cummins L- 10 EC15%0.2574			
1990-91	DDC 6V92TA DDECII	60%	0.31	931
	DDC 6V7 IN	25%	0.50	388
	Cummins L- 10	15%	0.46	232
1989	DDC 6V92TA DDEC II	25%	0.31	146
	DDC 6V7 IN	60%	0.50	350
	Cummins L-I0	15%	0.55	88
1988	DDC 6V7 IN	85%	0.31	334
	Cummins L-I0	15%	0.31	59
Pre I 988	DDC 6V7 I N	85%	0.50	4,682
	Cummins L-I0	15%	0.65	826

Adding these numbers suggests the following percentage breakdown:

DDC6V7T	66%
DDC6V92	19%
Cummins L-10	15%

There are undoubtedly some others some European engines some other Detroit Diesel and Cummins models.

Data were not available on annual vehicle kilometres travelled (VKT) for Canadian buses, so data from the *APTA Transit Fact Book* were used, with anecdotal information from Canadian transit agencies and one research program currently underway in Ottawa used as checks. Annual VKT estimates allow calculation of emission and fuel consumption totals.

The *APTA Transit Fact Book* reports 2,307.3 million bus miles in 1997 in the US transit industry, driven by 72,170 buses, for an average of3l,970 miles per bus. This converts to approximately 51,500 km. The *APTA Transit Fact Book* also reports that a total population of 13,147 Canadian transit vehicle (80% of which were buses) accumulated 469.1 million miles in 1996. If it is assumed that

[28] Environmental Protection Agency. 40 CFR parts 85 and 86. Control of Air Pollution from New Motor Vehicles and New Motor Vehicles Engines. July 27, 1992.

average miles per bus are the same as average miles per vehicle, this works out to 35,680 miles (57,400 km) per vehicle.

Anecdotal evidence from APTA and several Canadian transit agencies suggests that 60,000 km per bus is a reasonable annual accumulation. The distance travelled by a bus decreases with age. Based on the research program in Ottawa, however, the buses under test appear to be averaging substantially higher VICT; one bus had accumulated 39,699 km between tests (about 7 months apart), which corresponds to 68,000 km/year. [29] For the purpose of this report, we have assumed the following distribution of VKT:

- New to nine years old 65,000 km
- Ten to nineteen years old 50,000 km
- Twenty years and older 25,000 km

Comparing this to the bus population by model year, this works out to a total VKT of 605.3 million km, or 375.9 million miles. This compares well to the totals shown in the APTA *Transit Fact Book* 469.1 million miles total, but only 80% of the vehicles were buses, which suggests total bus mileage of 375.3 million miles. It also indicates an average of about 52,600 km per bus.

4. POTENTIAL CANADIAN BUS ENGINE REBUILD PROGRAM

4.1. Background and Rationale for a Rebuild Program

Particulate Matter (PM) is a probable carcinogen. High levels of exposure can increase the incidence and severity of asthma, bronchitis, and other respiratory problems. [30] California declared diesel PM emissions as a toxic air contaminant in l998. [31]

In the early 1990s, emission standards for PM tightened considerably for all diesel engines, but especially for urban buses. By 1993, the PM standard had dropped from 0.60 g/bhp-hr to 0.10

[29] Brown, Kevin, Rideout, Greg, and Turner, Jeffery. *Urban Driving Cycle Results of Retrofitted Diesel Oxidation Catalysts on Heavy Duty Vehicles: One Year Later.* SAE Paper 970186. February in 1997. The bus in question is Bus Number 8922, reporting odometer readings of 591,680 on November 22, 1995 and numbers 8901/60 are 1989 model year vehicles. Not all transit agencies will accumulate VKT at the rate of Ottawa's buses.

[30] Environmental Protection Agency. *Environmental Fact Sheet: Approval of Urban Bus Retrofit/Rebuild Equipment.* EPA 420-F-97-038. October 1997.

[31] California Air Resources Board. Resolution 98-49: Board Urges Use of New Federal TEA-21 Funds to Clean California's Transit and School Bus Fleets. Resolution dated September 24, 1998. Accessed via Internet at http://www.arb.ca.gov/tea-21/r98-49.htm. Page updated April 21, 1999.

g/bhp-hr. In 1994, this dropped again to 0.07, and in 1996 to 0.05 g/bhp-hr. [32]

There was considerable interest among those interviewed in a bus engine rebuild program for Canada. Advice ranged from avoiding the EPA Option 2 fleet averaging format, to reducing the number of choices, to ensuring that competitive offerings were available for the various engine families. [33]

A number of kit and engine manufacturers have successfully certified kits under the EPA Program (see Appendix F). Most of these kits - at least the ones that are certified to meet the 0.10 g/bhp-hr standard - focus on the DDC 6V92 TA engine family or its Cummins equivalent. For the older DDC 6V7TN and its Cummins equivalent the kits ate available only to the 250/0 reduction standard.

By using the PM emissions detailed in Table 4, converting g/bhp-hr to g/km, and multiplying by the estimated VKT per bus and the bus population, an estimate of the current emissions of PM can be developed. The annual PM emissions are estimated at 995.4 tonnes of PM in 1998 (See Appendix D for details).

4.2. Approach to a Canadian Rebuild Program

There are three options to consider: status quo, adopt the FPA program, or create a unique Canadian program.

In the status quo case, there will be a natural attrition of the older buses and engines with the highest PM emissions. Although transit agencies appear to be keeping buses longer, engines do still wear out and therefore need to be rebuilt at regular intervals. Some transit agencies will use the EPA certified kits anyway [34], but others will not as there is a premium of perhaps $3,500. [35] Engines appear to be rebuilt roughly every seven years in Canada (about 450,000 km), although there is considerable variability in this practice, and usually are rebuilt no more than three times before

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[32] Urban bus engines are permitted to meet a standard of 0.07 g/bhp-hr in use, as opposed to a laboratory measurement of 0.05. The California standard has been somewhat tighter than the EPA standard, though the standards are now being harmonized. Source: “Heavy Duty Truck and Bus Engines”, fact sheet published by Ecopoint Inc., May 1999, available on the Internet at www.dieselnet.com/standards/us/hd.html.
[33] Option 2 was not seen positively by anybody interviewed, including the EPA Office of Mobile Sources, APTA, and the engine manufacturers, because of its complexity.
[34] Interview with Gary Strachan, Coastal Transit, Vancouver BC.
[35] The EPA allowable increment on the 25% kits is US$2,000 in 1992 dollars. Using a CPI ratio of 163.0/140.3 (per US Bureau of Labor Statistics - 1998/1992 average) and an exchange rate of 1.5, this works out to a 1998 price of approximately C$3,500. That is the *allowable difference* between the standard rebuild kit and the EPA certified kit.

being replaced. [36] Under the US program, a “rebuild" is very tightly defined (see Appendix E); in any situation where an engine is disassembled, or major components are replaced on two or more cylinders, it is considered a “rebuild" and the program provisions are triggered. In Canada, transit agencies often undertake partial rebuilds to solve specific problems at an affordable cost.

If the US EPA program were adopted, it could add an immediate financial burden to the transit industry of as much as $3.) million per year. [37] This is a worst case scenario; many kits being purchased are already EPA certified, and small transit agencies might he exempted. [38]

A Canadian program would present an opportunity to recognize the different engine models and age structure in the Canadian transit fleet, and would also allow recognition of the difference in transit funding. A Canadian program could learn from the pitfalls experienced in rolling out the EPA's program, and present a significant advantage to Canadian transit fleets striving to maintain or increase ridership. Intensified public concern about Greenhouse Gas (GHG) emissions could be built into a Canadian program (they are not considered in the EPA Program).

One Canadian alternative, for example, would be to include purchase of a new engine. Replacing a 1988 DDC 6V7l with a new DDC Series 50 engine would reduce PM emissions from 0.50 g/bhp-hr to 0.05 g/bhp-hr, and would have the added advantage of increased fuel economy and lower regulated emissions. [39] The cost difference between a rebuild kit and a new engine, however, may be as high as $50,000. [40]

The DDC 6V71N is a transversely mounted, mechanically controlled, two-stroke engine. The current DDC Series 50 is a longitudinally mounted, fully electronic, four-stroke engine. Making the

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[36] Coastal Transit (Vancouver) rebuilds engines every seven years (about 420,0900 km); OC Transpo rebuilds buses when needed. APTA staff indicated that rebuilds occur at 250,000 miles for the first one, and about every 200,000 miles thereafter (roughly 400,000 and 325,000 km). APTA also indicated that newer buses typically accumulate about 50,000 miles per year, dropping to about 30,000 miles for older buses (80,000 to 48,000 km); Canadian transit properties suggested somewhat lower annual distance traveled as discussed previously.

[37] Detroit Diesel estimates sales of approximately 600 rebuild kits per year in Canada; if all were formerly :standard: kits and them were required to be EPA certified kits, the cost would rise. The 25% kits essentially consist of a catalytic converter muffler, with an incremental cost of about C$3,000, which would apply to approximately 80% of the engine totalling roughly C$1.44 million. For the other 20%, the EPA permits an incremental cost of $7,940 (1992$); based on the US CPI and an exchange rate of 1.5, that totals C$!.66 million for an aggregated cost of $3.1 million.

[38] Of Canada’s 117 transit properties listed in the Street Side Guide, 55 have fewer than 20 buses each and 84 have fewer than 40 buses. These 84 properties account for approximately 1440 buses (just over 12% of the population).

[39] One transit property indicated fuel economy improvement of about 10-15%, and another suggested that a smaller Series 40 engine was a possibility, further increasing fuel economy. Better fuel economy also reduces Greenhouse Gas emissions. Detroit Diesel suggested that the Series 40 was likely to prove too light for most transit service, and suggested a more conservative 5% fuel economy advantage.

[40] Detroit Diesel suggested that repowering could include rewiring the entire bus, new transmission, new cooling systems, turbo and blower, and physical modification in the engine compartment for a total cost approaching $40,000 US (worst case).

transition is not a simple installation; for example, compatibility with the existing drivetrain, cooling package, and the physical fit in the engine compartment pose serious challenges. The upgrade would include rewiring the entire bus to accept the electronics (some of which are controlled from the footpedal).

Replacing a muffler with a catalytic converter-muffler unit, which comprises the hulk of the incremental cost difference between the certified FPA kit and the standard rebuild for a 6V71 engine, will yield a reduction in PM emissions. Research underway at OC Transpo in Ottawa indicates substantial reductions in PM emissions are achieved with a converter muffler alone.[41]

Environment Canada has a tradition of supporting voluntary programs. This Bus Engine Rebuild Program would fit comfortably into this mold, which would limit the new staff required for kit certification and audit purposes. Supporting the program with funding would make it attractive to a transit industry chronically short of cash.

4.3. The Program

It is believed that a voluntary grant-based program would be the most likely program to succeed in Canada. The transit fleet is divided into three segments:

- Model years before 1979, ineligible for the program due to their age;
- Model years 1979 to 1995, which will be eligible;
- Model years 1994 and newer, which will be ineligible for the program as they already conform to a PM standard of 0.07 or 0.05 g/bhp-hr.

Within the eligible segment, there are two sets. For model years 1979 through 1985, which have probably been rebuilt twice and are facing their last 7 - 10 years of useful service at low annual km, a converter muffler would be installed,[42] supported by a grant of $2,500. The objective would be to convert the 2,948 buses in this segment over a three-year period, and this conversion could be keyed to the normal rebuild schedule or could simply be offered as an upgrade on a first come first served basis. The converter-muffler also reduces HC and CO by as much as 50%, although it has

[41] Brown, K., Rideout, G.R., and Turner, J.E. *Urban Driving Cycle Results of Retrofitted Diesel Oxidation Catalysts on Heavy Duty Vehicles: One Year Later*. SAE Paper 970186. February 1997.
[42] There are currently four manufacturers of converter mufflers certified under the EPA program: Engelhard, Engine Control Systems, Johnson-Matthey, and Nelson.

little effect on NOx or GHG emissions. [43]

The second group, model years 1986 through 1993, which may be considered to have much more service life ahead (and currently at higher annual km), would be eligible for an engine replacement program. Under this program, engine replacement could be supported by a grant of up to $25,000. The program would take place over the period 2000 to 2008, and would then end. The objective would be to re-engine the 4,050 hoses in this group with engines certified at the 0.05 g/bhp-hr level for PM emissions, which have the added advantage of higher fuel economy and lower regulated emissions (NC, CO, NOx). The higher fuel economy would result in lower GHG emissions.

Some transit agencies do operate DDC 6V92 engines, for which an EPA certified kit is available to reduce PM emissions to 0.10 g/bhp-hr. If the existing engine is electronic, this rebuild can be done relatively cheaply the DDC kit (which includes aftertreatment) retails at US$12,495 (about C$18,750).[44] A grant of $2,500 should cover the incremental cost. If the engine is mechanical, however, there is substantially more work involved in the rebuild.

Similar opportunities would apply in the case of transit buses powered by Cummins engines. The most common choice for older buses is the Cummins L-l0. Newer buses are powered by the C8.3 series engines or the ISM-280. Estimates of market share from Cummins, Detroit Diesel, CUTA, and others place the Cummins market share at between 15 and 20%.

[43] Interview with Kevin Brown, Engine Control Systems, and Kevin Hallstrom, Engelhard.
[44] Interview with Mark Johnston, Detroit Diesel.

TABLE 5 — EFFECT OF PROGRAM

Model Year	No. Buses	PM Standard (g/bhp-hr)	Last Engine Rebuild	Next Engine Rebuild	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
pre 1979	1796	0.50	1999		not expected to receive another rebuild										
1979	270	0.50	1993	2000	0.50	0.33	0.33	0.33	0.33	0.33	0.33	0.33	ret		add c-m in 2000
1980	372	0.50	1994	2001	0.50	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	ret	add c-m in 2000
1981	665	0.50	1995	2002	0.50	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	add c-m in 2000
1982	707	0.50	1996	2003	0.50	0.50	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	add c-m in 2001
1983	244	0.50	1997	2004	0.50	0.50	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	add c-m in 2001
1984	219	0.50	1998	2005	0.50	0.50	0.50	0.33	0.33	0.33	0.33	0.33	0.33	0.33	add c-m in 2002
1985	471	0.50	1999	2006	0.50	0.50	0.50	0.33	0.33	0.33	0.33	0.33	0.33	0.33	add c-m in 2002
1986	378	0.50	1993	2000	0.50	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	re-engine in 2000
1987	386	0.50	1994	2001	0.50	0.50	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	re-engine in 2001
1988	393	0.50	1995	2002	0.50	0.50	0.50	0.05	0.05	0.05	0.05	0.05	0.05	0.05	re-engine in 2002
1989	584	0.50	1996	2003	0.50	0.50	0.50	0.50	0.05	0.05	0.05	0.05	0.05	0.05	re-engine in 2003
1990	778	0.30	1997	2004	0.30	0.30	0.30	0.30	0.30	0.05	0.05	0.05	0.05	0.05	re-engine in 2004
1991	773	0.30	1998	2005	0.30	0.30	0.30	0.30	0.30	0.30	0.05	0.05	0.05	0.05	re-engine in 2005
1992	491	0.30	1999	2006	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.05	0.05	0.05	re-engine in 2006
1993	247	0.10	0	2007	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.05	0.05	re-engine in 2007
post 1993	2829	0.05	0	2008	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	

4.4. Partners

Potential partners for a rebuild program include the provincial governments and Canadian Urban Transit Association (CUTA).

Information transfer regarding the program was an issue mentioned frequently by the people interviewed regarding the US EPA's program. While EPA staff spent a great deal of effort presenting information on the program through APTA meetings, there were some who felt the information transfer didn't go far enough.

For Environment Canada to launch a rebuild program effectively, it would be desirable to meet with provincial governments and CUTA to present the rationale and benefits of the program. The Federation of Canadian Municipalities could also be a useful ally.[45]

5. POTENTIAL PROGRAM COSTS AND BENEFITS

5.1. The Costs

The cost of the EPA 0.1 kit for a DDC 6V92TA DDECII engine is US$12,495 retail, or C$18,750.[46] This compares to a standard rebuild for a 6V71 in the order of C$15,000.[47] The cost of simply replacing the existing muffler with a converter muffler would be in the order of C$2,500 to $3,000.[48]

The cost of replacing a DDC 6V71 with a new Series 50 can range from $20,000 to $50,000.[49] The cost of replacing a Cummins L-l0 would be similar.[50] If an average rebuild costs $15,000 and an

[45] At this time, no discussions have been initiated with provincial governments or the Federation of Canadian Municipalities. CUTA, when contacted, indicated limited willingness to participate in any meaningful way in the absence of a membership in the association by Environment Canada.
[46] Interview with Mark Johnston, Detroit Diesel, using 1.5 to convert US to Canadian dollars.
[47] Interview with Gary Strachan, Coastal Transit, confirmed by a call to Harper Diesel in Toronto. Harper Diesel quoted a base price of $10,990 plus any castings, electrics, accessories, etc. Generally, they try to find good used parts for a rebuild, rather than new. A used crankshaft in good condition can cost about $1,500, so an actual rebuild cost of $15,000 is likely, and may even be low.
[48] Detroit Diesel quotes a retail price of US$1,876, about C$2,800.
[49] Gary Strachan, Coastal Transit suggested $20,000. However, Mark Johnston at Detroit Diesel indicated that this estimate is low, representing the engine cost alone. To make the replacement, there would be additional work required such as rewiring, new cooling system, potentially a new transmission, for example. He suggested a cost of up to US$40,000. A call to Harper Diesel, a Toronto DDC distributor, confirmed that C$50,000 was a likely ballpark figure for swapping out a DDC 6V71 for a DDC Series 50.
[50] Clarke Ahrens, Cummins, indicated that a reconditioned Cummins L-10 could be installed for little for than the cost of the engine, and would produce PM of about 0.25 g/bhp-hr. Replacing the engine with a new ISM-280 transit engine would cost

engine replacement costs $50,000, the incremental cost of choosing to repower would be $35,000. However, this cost would be mitigated by savings in both fuel consumption and maintenance cost.

The estimates for fuel economy improvement between a 6V71 and a new Series 50 range from 5% [51] to 15% [52]. As a proxy, it was decided to use US fuel consumption and mileage travelled figures published by APTA. The Table below compares figures for 1997 (the most recent year available) to 1990 (when many engines would have been 6V71 or 6V92 models). The difference is 8%, which is consistent.

TABLE 6 - COMPARISON OF FUEL CONSUMPTION IN THE US TRANSIT FLEET, 1990 TO 1997

Year	Vehicle Miles (million)	Diesel Fuel (000 US gals)	MPG (miles/US gal)	km/L
1997	**2,307.3**	**563,512**	**4.1**	**1.7**
1990	**2,129.9**	**563,151**	**3.8**	**1.6**

Using this difference in fuel consumption, an estimation the Canadian transit fleet (on a per bus basis).

TABLE 7 - ESTIMATION OF FUEL SAVINGS AFTER REPLACING ENGINE

Item	VKT	FCR (L/km)	Annual Fuel (L)	Cost	Comments/Assumptions
Engine & installation				$50,000	Replace DDC 6V71 N with Series 50
Engine rebuild				$15,000	Conservative cost - deducted
Fuel prior to rebuild	65,000	0.7062	45,903		Assumes 70.62 LII00 km (4 mpg), 65,000 km/year
Fuel post rebuild	65,000	0.6497	42,231		Assumes 8% benefit
Fuel savings			3,672	$10,283	Assumes life cycle of 7 years, 40¢/L
Maintenance savings benefit				$1,028	Assumes 10% of fuel economy
Net cost				$23,689	

If the entire target population for the converter muffler takes up the program, the cost would he 2,948 buses x $2,500 per bus, or $7.37 million over three years.

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in the order of US$20,000 to $40,000.

[51] Mark Johnston, Detroit Diesel.

[52] Gary Strachan, Coastal Transit. Mr.Strachan indicated that he had seen an improvement from 4 mpg to 4.5 mpg between a 6V92 and a Series 50 - roughly 12%.

If the entire population eligible for the re-engine grant takes up the option, the total cost over eight years would be

4,030 buses x 0.19 DDC 6V92 DDEC x $2,500 per rebuild kit =$1.91 million
+ 4,030 buses x 0.81 older engines x $25,000 per bus = $81.61 million
$83.52 million

This totals $90.89 million over eight years. Assuming the expenditures could be spread evenly over the life of the program, the budget would be $12.9 million per year for the first three years, and $10.44 million per year to March 31, 2008.

5.2. *The Benefits*

Much of the preceding discussion has been based on theoretical levels of emissions, or certification levels as calculated by the EPA. An ongoing research program in Ottawa, conducted by OC Transpo and Environment Canada, has developed some estimates of real world performance of a catalytic converter muffler in a bus.

TABLE 8 - EMISSIONS DATA FROM OC TRANSPO RESEARCH[53]

Bus Measurement	Emissions (g/km)			
	PM	HC	CO	NOx
Bus 8423 (baseline)	1.53	3.00	22.72	16.54
Bus 8423 (catalyst)	0.96	0.91	4.23	15.87
Difference	0.57	2.09	18.49	0.67
Percentage Difference	37.3%	69.7%	81.4%	4.1%
Bus 8548 (baseline)	1.34	2.35	24.24	18.97
Bus 8548 (catalyst)	0.94	0.65	8.14	18.30
Difference	0.40	1.70	I 6.10	0.67
Percentage Difference	29.9%	72.3%	66.4%	3.5%
Average Reduction	0.49	1.90	17.30	0.67

In the absence of a rebuild kit certified to the 0.10 g/bhp-hr level for the DDC 6V71, the quickest and easiest route to lower PM emissions is adding a converter muffler. Based on the results obtained in the OC Transpo/Environment Canada tests (Table 8), and considering the benefit over 7 years at 65,000 km/year, this could reduce PM emissions by approximately

0.49 g/km x 65,000 km/year x 7 years = 223.0 kg.

[53] Brown, K., Rideout, G.R., and Turner, J.E. *Urban Driving Cycle Results of Retrofitted Diesel Oxidation Catalysts on Heavy Duty Vehicles: One Year Later*. SAE Paper 970186. February 1997. Measurements were taken on the chassis dynamometer at Environment Canada's River Road test facility, using the New York composite test cycle. The authors believe that this test cycle is representative of a transit bus in actual operation. Bus 8423 is a GMC Classic powered by a DDC 6V71N, tested on December 9, 1995, with an odometer reading of 775,554 km at the time of test. Bus 8548 is also a GMC Classic powered by a DDC 6V71N, tested on January 4, 1996, with an odometer reading of 819,988 km at the time of test.

For a grant of $2,500, the cost effectiveness would be

$2,500/223.Okg = $11.21/kg

However, the test results indicate substantial reductions in HC and CO as well, along with modest reductions of NOx. If these emissions arc combined into an emissions index and are valued at the same weight:

PM: 0.49 g/km x 65,000 km/year x 7 years = 223.0 kg.
HC: 1.90 g/km x 65,000 km/year x 7 years = 864.5 kg
CO: 17.30 g/km x 65,000 km/year x 7 years = 7,871.5kg
NOx: 0.67 g/km x 65,000 km/year x 7 years = 304.9 kg

The cost effectiveness would be

$2,500 / 9,263.9 kg $0.27/kg

Replacing the older 6V71 technology with new Series 50 technology represents a much greater opportunity for emissions reduction, nor only of PM and regulated emissions, but also of Greenhouse Gases (GHG). Table 9 indicates that emission standards for HC and CO are the same. NOx drops by 33%, and PM drops by better than a factor of ten.

TABLE 9 - COMPARATIVE EMISSION STANDARDS[54]

	1990	1998	Difference (g/bhp-hr)	Difference (g/km)[55]
NOx	**6.0**	**4.0**	**2.0**	**1.2**
HC	**1.3**	**1.3**	**0**	**0**
CO	**15.5**	**15.5**	**0**	**0**
PM	**0.60**	**0.05**	**0.55**	**0.34**

In calculating the benefits of replacing the 6V71N with a Series 50, the emissions reductions have been prorated to reflect the changed standards; where the standards are the same, the estimated emissions reductions are the same. For example, the PM emissions estimate for the DDC 6V71 is the arithmetical average of the two tests conducted in Ottawa. The estimate for the Series 50, in order to be representative of in-use performance, is the 6V71 figure times the ratio of the two applicable standards (0.05/0.60).

[54] Schiavone, John. *Retrofit of Buses to Meet Clean Air Regulations.* National Academy Press (Transportation Research Board). 1994.
[55] Calculated by multiplying g/bhp-hr x 7.9 per EAP practice, which gives g/mile, and then dividing by 1.61 to give g/km.

TABLE 10 - ESTIMATED EMISSIONS REDUCTIONS FOR NEW ENGINE (IN USE)

	6V71N **Difference** (Baseline - no catalyst)	**Series 50** (Prorated per Standard, + catalyst)	
PM	1.44	0.12	1.32
HC	2.68	0.78	1.90
CO	23.48	6.18	17.30
NOx	17.76	11.84	5.92

Using the figures shown above, the estimated emissions reduction for PM alone would be

1.32 g/km x 65,000 km/year x 7 years = 600.6 kg.

For a grant of $25,000, the cost effectiveness would be

$25,000/600.6kg = $41.63/kg

However, if the reductions in HC, CO, and NOx are combined into an emissions index and are valued at the same weight:

PM: 1.32 g/km x 65,000 km/year x 7 years = 600.6 kg.
HC: 1.90 g/km x 65,000 km/year x 7 years = 864.5 kg
CO: 17.30 g/km x 65,000 km/year x 7 years = 7,871.5 kg
NOx: 5.92 g/km x 65,000 km/year x 7 years = 2,693.6 kg

The cost effectiveness would be

$25,000 /12,300.2 kg = $2.03/kg

If the reduction in GHG emissions is factored in, the cost effectiveness becomes even more attractive. Based on the calculations shown in Table 7, the annual fuel savings are 3,672 L/year, or 25,700 L over the seven year period. GHG production is proportional to fuel consumption at the rate of 2.764 kg/L. [56] The GHG reduction will be

25,700Lx2.764kg/L = 71,034.8kg

[56] Instrumental Solutions. *The Potential for GHG Reductions from Scrappage Programs for Older Trucks and Engines*. Prepared for the Trucking Sub-Group, National Climate Change Transportation Table. June 1999.

Adding the GHG reductions to the other emissions reductions, the total cost effectiveness is

$25,000 I 83,065 kg = $0.30/kg.

6. PROVINCIAL ROLE

The provincial governments have traditionally held jurisdiction over transit, and have administered comprehensive transit funding programs. In recent years, this funding role has been reduced to the point where there is virtually no remaining provincial transit funding.

This does not mean that the provinces will be completely disinterested if a federal government program to encourage bus engine rebuilds is announced. It is likely that provincial governments will wish to take on some role within the program.

Vehicle inspection and maintenance programs such as AirCare in BC and Drive Clean in Ontario are also relevant. Although AirCare began as a light duty vehicle program, it Is now being expanded to include heavy dun vehicles, such as buses. Drive Clean is set to follow a similar path. These programs could prove to be useful catalysts in rolling out and monitoring the bus engine rebuild program.

7. LABOUR ISSUES

In considering a rebuild program, there are two labour-related issues to address: first, will the unions involved in transit maintenance activities see such a program as an opportunity or a threat, and second, is there an educational or apprenticeship potential.

The principal (but not only) union involved in transit is the Amalgamated Transit Union. In discussions with the transit industry, the opinion was that there is unlikely to be any union impact of a bus engine rebuild program. [57]

[57] Based on discussions with Jerry Trotter and Frank Cihak, APTA, and Mike Roschlau, CUTA. Unable to contact Ken Foster, Amalgamated Transit Union.

There is unlikely to be any opportunity for an apprenticeship program or educational support through community colleges. When an engine is rebuilt, certain parts are replaced and others are added (e.g. a converter muffler). However, the difference between a standard engine rebuild and a rebuild to an environmental standard is the difference between installing Part A or Part B. There does not appear to be any need to conduct the work in a markedly different way.[58]

8. TIME SCALE FOR THE PROGRAM

8.1. EPA Urban Bus Engine Retrofit Rebuild Program

The EPA program was called for as part of the Clean Air Act, and particularly the Clean Air Act Amendments of 1990. There was a lengthy consultation period in which a Notice of Proposed Rulemaking was issued, comments were received, background reports were prepared, workshops were conducted, and a Final Rule was promulgated. This consultation extended from September, 1991 to April, 1993. The Final Rule was published in the Federal Register on April 21, 1993. The program actually came into effect (i.e. transit operators seeking to rebuild an engine had to comply with the program's requirements) as of January 1,1995.

Because the program applies to pre-1994 model year engines, there will come a time when no more of these engines exist in the transit population. There is no planned expiry date for the program, but the program administrators expect that fewer than half the estimated target population of 35,000 buses will remain in service by 2006.[59] According to the estimated emissions benefits shown in Table 1, the program will be complete in 2008.

8.2. Canadian Bus Engine Rebuild Program

Because the Canadian market for transit buses and engines is so small,[60] there is no difference in the engines manufactured for Canadian or US transit fleets. Therefore, engines manufactured in 1994 and later, sold in Canada, conform to the EPA's PNI standards; leading into 2004, they will comply with the new combined NOx and PM standard currently being introduced.

[58] Based on interviews with transit operators, engine manufacturers, and APTA staff.
[59] Interview with Anthony Erb and Bill Rutledge, EPA.
[60] The *APTA Transit Fact Book* indicates sales of about 6,000 buses per year over the last four years. Estimates by Detroit Diesel and Cummins suggest that the Canadian market is about 600 buses per year. Both these figures are minuscule, relative to the number of new heavy duty trucks sold each year.

For that reason, it is suggested that the program apply only to pre-1994 engines, as does the EPA program. However, Canadian transit agencies keep their vehicles in service longer than US transit agencies. The average age of a bus in the US, according to APTA sources, is about eight years. In Canada, according to CUTA sources, it is closer to 12 years. If US buses are retired at the age of *15,* it is likely that Canadian buses are retired at the age of 23, which suggests that the last 1993 Model Year bus would he retired in 2016. However, it should be noted that the oldest model year shown in active service in the *Street Side Guide to Urban Transit Fleets* was 1960, so the retirement age of 23 could be optimistic.

There probably isn't a need to maintain a program to 2016, however. If engines are rebuilt every seven years, the entire population of engines would be rebuilt over a rolling seven year time period. With attractive funding, this could potentially he accelerated.

It would take approximately a year to introduce the program, define all the parameters, consult with the industry and the provinces, and establish program documentation in both official languages. A program could therefore have an effective date of July 1, 2000 and a sunset date of March 31, 2008.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1. Conclusions

The Urban Bus Engine/Retrofit Rebuild Program, administered by the EPA, has been a success in its quoted objective of reducing PM emissions in the largest urban areas of the US. In its peak year, the program is estimated to reduce PM emissions by approximately 800 tonnes.

The structure of the program, offering either a standards based option geared to engine type or a fleet averaging option, has proved unnecessarily cumbersome. All those involved agree that it would he preferable to establish a simpler program geared to engine types and standards.

There have been relatively minor breaches of the program, as determined by the audit process. However the audit is a visual inspection program of a sample of buses and records at a transit fleet, rather than a test program to determine in-use performance. Consequently, it is not clear that the calculated PM emission reductions, based on engine and kit certification levels, are actually achieved on the road.

Certification of the kits is on the basis of manufacturer tests and cost calculations. There is some question whether a kit tested on an engine dynamometer accurately reflects the performance of that kit in a bus. Manufacturers of converter mufflers and engine manufacturers are concerned about such issues as backpressure and durability, and to some extent the potential for a kit to create problems in other parts of the engine-drivetrain system.

There is a substantial difference between the Canadian and the US transit market. Canadian fleets keep their vehicles longer (average age of 12 years compared to eight), use predominantly the mechanical DDC 6V71N mechanical engine (compared to the DDC 6V92TA DDECII in the US), and receive little or no federal or provincial funding. For this reason, it is believed that if a rebuild program is to be introduced, it should be a Canadian program rather than an adoption of the US EPA program.

Given the age and engine types in the Canadian market, an aftertreatment program is the quickest means to achieve substantial reductions in PM emissions. Such a program could also have substantive effects on HC and CO emissions, and a smaller impact on NOx.

An engine replacement program is attractive in its ability to rapidly introduce much cleaner engines. However, there are substantial costs associated with an engine replacement program, arising from factors such as the conversion from two stroke to four stroke, the need for rewiring the bus to accommodate electronic control, replacing the transmission, etc.

While the Detroit Diesel family is predominant in the industry, Cummins has approximately a 15 - 20% market share. However, the same issues apply - the engines in the Canadian market tend to be mechanical and replacing them with today's electronically controlled technology would be expensive.

The benefits accruing to a replacement program are very large, principally due to the GHG reductions resulting from switching to a more fuel efficient engine. Transit buses tend to use a lot of fuel and since GHG emissions are proportional to fuel consumption a small change in fuel efficiency can yield a large saving in GHG over the lifetime of a bus. The PM benefits are also very large, due to the concentration of transit usage in congested, peak period urban environments.

The transit industry is underfunded at this time. A program that imposes extra costs will face resistance; a program that includes funding will be more likely to gain acceptance.

9.2. Recommendations

It is recommended that Environment Canada:

Consult extensively with the provincial ministries responsible for transit and environment, the Canadian Urban Transit Association, and the Federation of Canadian Municipalities to build alliances and administrative partnerships;

Initiate a program that includes a funded installation of converter mufflers over a three-year period, on a first come first served basis, for engines of model years 1979 to 1985 inclusive - funding to be the cost of the installed converter muffler to a maximum of $2,500;

Initiate a program that encourages the *use* of the FPA 0.10 g/bhp-hr rebuild kit at the rime of rebuild, where this kit is available, with *a* grant of no more than $2,500;

Initiate a program allowing replacement of a 1986 to 1995 model year (inclusive) engine with a new engine meeting the PM standard of 0.05 g/bhp-hr, on a voluntary basis, funded at the level of $25,000;

Monitor the program to determine the level of take-up for each of the three options;

Conduct periodic chassis dynamometer tests of vehicles after installation to determine the effectiveness of the program to reduce PM emissions;

Market the program extensively through CUTA and through a purpose-built web site;

Introduce the program effective July 1, 2000, and end it on March 31, 2008.

APPENDICES

APPENDIX A CONTACTS

Last	First	Company	City	State/ Prov.	Country	Phone
Ahrens	Clarke	Cummins Diesel			USA	812-377-3263
Alexander	David	US EPA	Washington	DC	USA	202-564-2109
Aubin	Karen	Environment Canada	Ottawa	ON	Canada	613-998-9590
Brown	Kevin	Engine Control Systems	Newmarket	ON	Canada	905-853-5500
Cihak	Frank	APTA	Washington	DC	USA	202-898-4000
Dreolini	Tony	Winnipeg Transit	Winnipeg	MB	Canada	204-986-5774
Duerr	John	Detroit Diesel Corp	Detroit		USA	313-592-7090
Erb	Anthony	US EPA	Washington	DC	USA	202-564-9259
Foster	Ken	Amalgamated Transit Union	Mississauga	ON	Canada	905-670-4710
Hallstrom	Kevin	Engelhard			USA	732-205-6489
Hemily	Brendon	CUTA	Toronto	ON	Canada	416-365-9800
Johnston	Mark	Detroit Diesel Corp	Detroit	Ml	USA	313-592-7151
Krowchuk	Rick	Coastal Transit	Vancouver	BC	Canada	604-540-3184
Lassen	Martin	Johnson Matthey Inc.			USA	610-341-3404
Lupkoski	Bill	Cummins Diesel	Mississauga	ON	Canada	905-795-0050
Onodera	David	CUTA	Toronto	ON	Canada	416-365-9800
Roschlau	Mike	CUTA	Toronto	ON	Canada	416-365-9800
Rutledge	William	US EPA	Washington	DC	USA	202-564-9297
Strachan	Gary	Coastal Transit	Vancouver	BC	Canada	604-293-4631
Trotter	Jerry	APTA	Washington	DC	USA	202-898-4087
Turner	Jeff	Toronto Transit	Toronto	ON	Canada	416-393-3850
Voorhees	Mike	Seattle Metro	Seattle	WA	USA	206-684-1629
Wehr	Mike	MilwaukeeTransit	Milwaukee	MN	USA	414-937-3238
Wright	Adrian	OC Transpo	Ottawa	ON	Canada	61 3-842-3636

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APPENDIX C ENGINES AND EMISSIONS (US PROGRAM)

Model Year	**Engine Model**	**% of Affected Population**	**Pre-Rebuild PM Level (g/bhp-hr)**
1993	DDC 6V92TA DDEC II	75%	0.10
	Cummins L-l0 EC	25%	0.10
1992	DDC 6V92TA DDEC II	75%	0.25
	Cummins L-l0 EC	25%	0.25
1990 - 91	DDC 6V92TA DDEC II	75%	0.31
	Cummins L-I0	25%	0.46
1989	DDC 6V92TA DDEC II	75%	0.31
	Cummins L-I0	25%	0.55
1988	DDC 6V92TA DDEC II	55%	0.3
	Cummins L- 10	25%	0.31
	Other	20%	0.50
987	DDC6V92TA	42%	0.50
	DDC 6V92TA DDEC I	37%	0.30
	Cummins L-l0	10%	0.65
	Other	11%	0.50
1986	DDC6V92TA	51%	0.50
	DDC 6V92TA DDEC I	12%	0.30
	Cummins L-l0	1%	0.65
	Other	36%	0.50
1985	DDC 6V92TA	68%	0.50
	Other	32%	0.50
1984	DDC 6V92TA	90%	0.50
	Other	10%	0.50
Pre-1984	All	100%	0.50

Source: US Environmental Protection Agency.

APPENDIX D ESTIMATED PM EMISSIONS INVENTORY (CANADA)

Model Year	No. Buses	Average PM (g/bhp-hr)	Multiplier	Average PM (g/km)	Annual km	Annual PM (tonnes)
up to 1978	1,796	0.52	4.91	2.55	25,000	114.6
1979	270	0.52	4.91	2.55	50,000	34.5
1980	372	0.52	4.91	2.55	50,000	47.5
1981	665	0.52	4.91	2.55	50,000	84.9
1982	707	0.52	4.91	2.55	50,000	90.3
1983	244	0.52	4.91	2.55	50,000	31.1
1984	219	0.52	4.91	2.55	50,000	28.0
1985	471	0.52	4.91	2.55	50,000	60.1
1986	378	0.52	4.91	2.55	50,000	48.3
1987	386	0.52	4.91	2.55	50,000	49.3
1988	393	0.31	4.91	1.52	50,000	29.9
1989	584	0.46	4.91	2.26	65,000	85.7
1990	778	0.38	4.91	1.87	65,000	94.4
1991	773	0.38	4.91	1.87	65,000	93.7
1992	491	0.25	4.91	1.23	65,000	39.2
1993	247	0.10	4.91	0.49	65,000	7.9
1994	618	0.07	4.91	0.34	65,000	13.8
1995	392	0.07	4.91	0.34	65,000	8.8
1996	710	0.07	4.91	0.34	65,000	15.9
1997	445	0.05	4.91	0.25	65,000	7.1
1998 (E)	664	0.05	4.91	0.25	65,000	10.6
	11,603					995.4

APPENDIX E WHAT IS AN ENGINE REBUILD?

Under the US EPA Engine Retrofit/Rebuild Program, rebuilding is defined as follows (Final Rule, April 21, 1993):

> "Engine Rebuild means an activity, occurring over one or more maintenance events, involving:
> 1. Disassembly of the engine including removal of the cylinder head(s); and
> 2. The replacement or reconditioning of more than one major cylinder component in more than half of the cylinders."

Once a transit agency begins to work on more than two cylinders, they are effectively conducting an engine rebuild and the program is triggered. A Canadian transit agency', however, may' perform major reconditioning (e.g. replacement of injectors, cylinder liners) on two or three cylinders, but not on others, depending on what is needed at the time. This can make a substantial difference in cost.

A full engine rebuild, according to Detroit Diesel, would typically include the following components:

- Blower
- Cylinder Heads
- Turbo
- Injectors
- Cylinder kits
- Overhaul gaskets
- Blower by-pass valve
- Bearings
- Re-qualifies/regrinds/replaces camshafts and other engine components as required

APPENDIX F — ENGINE REBUILD KITS CERTIFIED BY EPA

(Information supplied electronically by Mr. Bill Rutledge, US EPA, Office of Mobile Sources)

EQUIPMENT CERTIFIED & STATUS OF NOTIFICATIONS OF INTENT TO CERTIFY URBAN BUS EQUIPMENT

July 13, 1999 Public Air Docket A-93-42

	Certifier	Docket Category	Equipment Description	NIC Received	FR Notice: Start 45-day	End 45-day	Certification Date[1]
1	Engelhard 1	IV	Exh cat (CMX) for all 2 s/c exc '90 6L71TA (**triggers** 25% std, effective 12/01/95)	09- -94	59 FR 47581, 09-16-94	10-31-94	60 FR 28402, 05-31-95
2	Engelhard 2	V	Exh cat (CMX) and ceramitized engine parts (~ %). Option2 only	11- -94	60 FR 12185, 03-06-95	04-20-95	60 FR 47170, 09-11-95
3	Detroit Diesel Corp (DDC 1)	VII	Engine upgrade kit for DDC 6V92TA MUI's (25 %)	02-28-95 04-19-95	60 FR 29590, 06-05-95	07-20-95	60 FR 51472, 10-02-95
		(VII)	Life Cycle Cost Information	"	61 FR 8275, 03-04-96	04-18-96	EPA Ltr: 06-24-96 61 FR 37734, 07-19-96
4	Cummins	VIII	Eng upgrade for Cummins L10 mech injection mfrd from 11/85 - 12/92 (**triggers** 25% std effective 06/14/96)	03- -95	60 FR 32316, 06-21-95	08-07-95	60 FR 64046, 12-13-95
5	Twin Rivers Technologies	X	Biodiesel, exh cat (CMX) & timing retard: all 2 s/c exc '90 6L71TA (25 %)	06-29-95 08-21-95	60 FR 64051, 12-13-95	01-29-96	EPA Ltr: 09-20-96. 61 FR 54790, 10-22-96
6	Johnson Matthey 1	XI	Exh cat (CEM I) for all 2 s/c (25 %)	09-11-95	60 FR 64048, 12-13-95	01-29-96	EPA Ltr: 03-28-96. 61 FR 16773, 04-17-96
7	DDC 2	XII	Eng upgrade kit for DDC 6V92TA DDECII's (25%)	01-19-96	61 FR 16739, 04-17-96	06-03-96	61 FR 37738, 07-19-96
8	Engelhard 3	XIII	ETX kit: Exh cat, ceramitized parts, & eng upgrade parts for 49states 6V92TA MUI (**triggers** 0.10 std effective 09/15/97)	02-01-96	61 FR 20249, 05-06-96	06-20-96 07-19-96	EPA Ltr: 02-28-97 62 FR 12166, 03-14-97
9	Engine Control Systems 1	XIV	Exh cat for listed 2 s/c (25 %)	01-16-96	61 FR 41408, 08-08-96	09-23-96	EPA Ltr: 12-02-96 62 FR 746, 01-06-97
10	Johnson Matthey 2	XV	Exh cat (CEM II) & eng mods for 6V92TA MUI (0.10)	10-03-96, 12-01-96	62 FR 4528, 01-30-97	03-17-97	EPA Ltr: 09-08-97 62 FR 60079, 11-06-97
11	ECS 2	XVI	Exh cat for **all** 4 s/c (18%) & 1973-1984 8V71N (25%)	11-??-96	62 FR 32602; 06-16-97	07-31-97	EPA Ltr: **xx-yy-zz** 63 FR 4445; 01-29-98
12	Engelhard 4	XVII	Exh cat (CMX) for 1992 - 1993 Cummins L10 EC (**triggers** 25% std effective 09-21-98)	10-31-96	62 FR 32599; 06-16-97	07-31-97	EPA Ltr:: 02-12-98 63 FR 13660; 03-20-98
		(XVII)	Exh cat (CMX) for **all (?)** other 4 s/c (25 %)	04-20-98	63 FR 65780: 11-30-98	01-14-99	Under Review
		(XVII)	Life cycle cost info (for all 4 s/c) **would trigger** 25% std	>12-09-99	Under Review	<--	<--
13	NOPEC	XVIII	Biodiesel and exhaust catalyst for 2 stroke/cycle (25 %)	03-06-97	62 FR 62052; 11-20-97	01-05-98	Withdrawn
14	Nelson Industries	XIX	Exh cat for 2 s/c exc '90 6L71TA (25 %)	03-17-97	62 FR 37228; 07-11-97	08-25-97	EPA Ltr. 10-14-97 62 FR 63159; 11-26-97
15	DDC 3	XX	TurboPac, ECS exh cat and engine upgrade for 6V92TA MUI (0.10)	07-18-97	62 FR 60077; 11-06-97	12-22-97	EPA Ltr: 04-06-98 63 FR 26798; 05-14-98

16	Johnson Matthey 3	XXI	Exh cat (CEM II) and engine mods for 6V92TA DDEC1&2 (0.10)	10-14-97, 03-06-98	63 FR 26795; 05-14-98	06-29-98	EPA Ltr: 10-21-98 63 FR 66798; 12-03-98
		(XXI)	Life Cycle Cost Information for DDEC2	01-26-99	64 FR 11864; 03-10-99	04-26-99	Under Review
17	Engelhard 5	XXII	ETX kit: Exh cat, ceramitized parts and eng upgrade parts for 1988-93 6V92TA DDEC2 (**triggers** 0.10 in 49s & CA. Effective 03/22/99 delayed until 05/22/.99)	10-21-97	63 FR 17411; 04-09-98	05-26-98	EPA Ltr: 07-01-98 63 FR 50225; 09-21-98
18	Turbodyne Systems, Inc.	XXIII	TurboPac & ECS exh cat for 6V92TA MUI (0.10)	11-14-97	64 FR 19151; 04-19-99	06-03-99	<--
19	DDC 4	XXIV	Exh cat, eng upgrade etc, DDEC3, for 1985-93 49s & CA 6V92TA DDEC (0.10)	12-24-97	63 FR 13662; 03-20-98	05-04-98	EPA Ltr: 10-02-98 64 FR 9500; 02-26-99
20	Engelhard 6	XXV	ETX Plus technology for 1988-93 49s & CA 6V92TA DDEC II engines (0.10)	12-01-98	64 FR 23072; 04-29-99	06-14-99	Under Review
21	Johnson Matthey 4		CEM IV Cat Muffler for all 4 s/c engines (25 %)	12-22-98 ?	Under Review	<--	<--
22	Johnson Matthey 5		CRT self-regenerating filter for all 2 & 4 s/c diesel engines. Replmt for muffler. Reqrs < 50 ppm S diesel fuel. (0.10)	06-??-99			
23	Biodiesel Development Corp		20% biodiesel with oxidation catalyst plus optional injection retard	07-12-99			

Many Federal Register notices are available on the Office of Mobile Sources web site (http://www.epa.gov/omswww/) or the Government Printing Office web site (http://www.access.gpo.gov/su_docs/).

1. Exhaust catalytic muffler (CMX;) certified by Engelhard Corporation for all two-stroke/cycle engines.

The CMX is a catalytic converter that takes the place of the original noise muffler installed in the engine exhaust system. This kit is certified to meet the standard of reducing PM by at least 25 percent (see 60 FR 28402, May 31,1995, for the PM certification levels assigned to different engine models). Note that only one test engine was used for certification testing. We do not know the baseline emission levels for other engine models.

This certification triggers the 25% standard for all 2 stroke/cycle engines except the 1990 DDC 6L71TA.

2. CALY plus ceramic in-cylinder coating (GPX-4) certified by Engelhard Corporation for 1979 - 1989 DDC GV92TA MUJ engines.

The major components are a catalytic converter (the CMX described above), and a rebuild kit which incorporates a ceramic in-cylinder coating. This kit is certified for use only in compliance option 2, and is not certified to meet the standard of reducing PM by at least 25 percent (see 60 FR 47T70, September 11, 1995). Insufficient data was provided to determine that PM emissions were reduced by at least 25 percent, compared to a standard rebuild. The above data is used to establish a certification level of 0.25 g/bhp-hr for use by operators using compliance program 2 and having 1979 - 1989 DDC 6V92TA MUT engines.

3A. Upgrade Kit Certified for Detroit Diesel Corporation 1979-1987 6\[92TA MUJ Engines

This kit "upgrades" 1979 through 1987 model year 6V92TA urban bus engines having mechanical unit injection (MUI), to virtually a 1989 model year configuration. The kit includes gaskets, cylinder kits, fuel injectors, camshafts, blower assembly, turbocharger, and cylinder head assembly.

This kit is certified to meet the standard of reducing PM by at least 25 percent (see 60 FR 51472, October 2,1995).

3B Upgrade Kit certified for Detroit Diesel 1988 & 1989 6V92TA MUI Engines

Same as kit described in (A) above, except with different fuel injection timing. Note that the baseline test is different than in (A) above. This kit is certified to meet the standard of reducing PM by at least 25 percent (see 60 FR 51472, October 2,1995).

4. ***Cummins Engine Company's upgrade kit certified for certain model L TA] 0-B engines***

This kit is applicable to Cummins LTA1 0-B model engines originally manufactured between November 1985 and December 1992. The upgrade kit includes a camshaft, cylinder kits, fuel injectors, cylinder head, turbocharger, and fuel pump. This kit is certified to meet the standard of reducing PM by at least 25 percent (see 60 FR 64046, December 13, 1995). The certification PM level is established at 0.34 g/bhp-hr for the applicable engines using the kit.

This certification triggers the 25% standard for the applicable engines.

5. Catalyst (Engelhard's CMX), biodiesel additive and injection timing retard certified by Twin Rivers Technologies, Ltd, for certain two-stroke/cycle engines.

Two configurations of equipment are certified for applicable engines. (1) a particular biodiesel fuel additive in combination with a particular exhaust system oxidation catalyst; and, (2) the additive and the catalyst, plus retarded fuel injection timing. The certified equipment is applicable to petroleum-fueled Detroit Diesel

Corporation (DDC) two-stroke/cycle engines originally installed in urban buses of model years 1979 through 1993, excluding 1990 model year DDC 6L7TTA engines. The oxidation catalyst of this equipment is the CMX catalyst which has been previously certified under the urban bus program by the Engelhard Corporation. Biodiesel is a potentially renewable, oxygen-containing fuel. As a component of this certified equipment, biodiesel is produced from original-use plant oil sources and methyl alcohol, consists of methyl esters of specified carbon chain-lengths, and must be blended at a ratio of 20 percent by volume with the balance federally required low-sulfur diesel fuel (having a maximum sulfur content of 0.05 weight percent). This blend is referred to as “B20”. Some configurations of this equipment use retarded fuel injection timing to reduce exhaust emissions of NOx.

Some configurations of this kit are certified to meet the standard of reducing PM by at least 25 percent for the applicable engines. The 1990 - 1993 6V92TA IDDEC II engine models are certified only with timing retard because analysis of new engine certification data and other Twin Rivers data indicate that federal NOx standards would otherwise be exceeded with stock timing. See 61 FR 54790, October 22, 1996, for the PM certification levels assigned to different engine models.

6. Catalytic Exhaust Muffler (CEM-J) certified by Johnson Matthey, Inc., for two-stroke/cycle engines

This kit is certified to meet the standard of reducing PM by at least 25 percent for the applicable engines (see 61 FR 16773, April 17,1996, for the PM certification levels assigned to different engine models).

7. Upgrade Kit Certified by Detroit Diesel Corporation for its 6V92 TA DDEC II Engines

This kit "upgrades' 1988 through 1990 model year 6V92TA urban bus engines having Detroit Diesel Electronic Control (DDEC II) fuel injection, to a 1991 model year configuration. The kit includes gaskets, cylinder kits, fuel injectors, camshafts, blower assembly, turbocharger, cylinder head assemblies, and computer program for the 1991 model year 277 Hp engine configuration.

This kit is certified to meet the standard of reducing PM by at least 25 percent, and has a PM certification level of 0.23 g/bhp-hr. (See 61 FR 37738, July 19, 1996.)

8. Engelhard ETX rebuild kit for 1979-1989 DDC ~92TA MUJ engines.

The ETX kit, certified on March 14, 1997 (see 62 FR 12166), consists of an engine rebuild "upgrade" kit, a CMX-5 catalytic converter-muffler, a proprietary coating (referred to as the GPX-5m) applied to piston crowns and cylinder head combustion chambers. The engine upgrade portion of the kit includes cylinder kits, cylinder heads, camshafts, turbocharger, blower and drive gear, fuel injectors, and gasket kit. This equipment is certified to the 0.10 g/bhp-hr PM level, and as being available for less than the life cycle cost limit of$7,940 (in 1992 dollars).

This certification triggers the 0.10 g/bhp-hr PM standard for applicable engines.

9. Oxidation Catalytic Muffler (0CM) certified by Engine Control Systems for certain two-stroke cycle engines

This kit is an oxidation converter muffler to replace the standard bus muffler. It is certified to meet the standard of reducing PM by at least 25 percent for the applicable engines (see 62 FR 746, January 6, 1997, for the PM certification levels assigned to different engine models).

10. Johnson Matthey's CCT kit certified to the 0.lOg/bhp-hrstandardfor 1979 - 1989 DDC &v92TA MUJ engines.

The certified equipment, referred to by Johnson Matthey as the Cam Converter Technology (CCT) upgrade kit, consists of proprietary cam shafts, a CEM II catalytic exhaust muffler, and specified emissions-related engine rebuild parts and certain engine settings. The kit is applicable to all 6V92TA urban bus engine models made by Detroit Diesel Corporation (DDC) from model years 1979 to 1989 and equipped with mechanical unit injectors (MUI). Four horsepower ratings are available (253, 277, 294, and 325). The kit is certified to meet the life cycle cost requirements. Accordingly, the certification triggers the 0.10 g/bhp-hr standard for engines originally above 294 horsepower. (The certification of the Engelhard ETX kit on March 14, 1997 at 62 FR 12166, triggered the 0.10 g/bhp-hr standard for engine rated at 294 horsepower and less.)

The PM certification level is 0.10 g/bhp-hr for the applicable engines (see 62 FR 60079,11-06-97).

11. Engine Control System '5 converter muffler certified for four-stroke/cycle engines

This kit is an oxidation converter muffler to replace the standard bus muffler. The converter is intended to be used only by operators using compliance option 2 to provide a 18% reduction relative to the PM levels of either the original engine configuration or of the Cummins certified rebuild kit. The applicable engines are primarily the Cummins L10 engine models.

The PM certification levels sought for the equipment vary with specific engine calibration and are provided in the application.

12. Engelhard CMX catalyst for 1992 - 1993 Cummins L10 ***EC***

This kit is a catalytic muffler which replaces a standard muffler in an engine exhaust system, and is applicable to Cummins L1O EC engine models. This kit is certified to reduce PM emissions by at least 25 percent and to comply with the appropriate life cycle cost ceiling. The PM certification level is 0.19 g/bhp-hr. Certification was provided by letter dated February 12,1998, and described in a Federal Register notice dated March 20, 1998 (63 FR 13660).

This certification triggers the 25% standard for the applicable engines.

Additional emissions data was provided by Engelhard on April 20, 1998, which is intended to demonstrate 25 percent reduction on all other 4 stroke/cycle engines. A Federal Register notice (63 FR 65780:11-30-98) announces EPA receipt of the data and asks for public comment.

13. NOPFC~ catalyst (Engelhard's CMX), biodiesel additive and injection timing retard under review for certain two-stroke/cycle engines.

A notification of intent to certify that is virtually identical to, and relies on, the same exhaust emissions data of the above certification by Twin Rivers Technologies. NOPEC withdrew this application.

14. Nelson ***Division exhaust catalyst for two-stroke/cycle engines.***

This equipment consists of an exhaust catalyst/muffler used in place of the original muffler on a bus. It is certified to meet the *25* percent PM reduction standard for applicable engines. This equipment also complies with the $2,000 (1992 dollars) life cycle cost requirement.

15. Detroit Diesel Corporation Kit Certified for GV92TA MUJ engines.

This kit is intended to be certified for the 0.10 g/bhp-hr standard, and consists of the base engine components used on the 25% reduction kit certified by DDC on 10/2/95, the *25%* reduction catalyst previously certified by Engine Control Systems (1/6/97), and a TurboPac supercharger system supplied by Turbodyne Systems, Ltd. The equipment is applicable to DDC 6V-92TA MUI engine models for years 1979 to 1989. No life cycle cost information is provided.

In a letter to DDC dated April 6,1998, EPA certified this kit to the 0.10 g/bhp-hr PM standard.

16. Johnson Matthey,5 Cam Converter Technology (CCT) upgrade kit under review for ~92TA DDEC engines.

This certified kit, referred to by Johnson Matthey as the Cam Converter Technology (CCT) upgrade kit, is applicable to all federal and California Detroit Diesel Corporation (DDC) 6V92TA DDEC two-cycle diesel engine originally equipped in an urban bus from model years 1985 to 1993. The kit consists of proprietary cam shafts, a CEM II catalytic exhaust muffler, an 0.015 offset key, and specified emissions-related engine rebuild parts and certain engine settings. Two horsepower ratings are available (253 and 277). No life cycle cost information has been submitted. The offset key replaces the standard Woodruff key between the pulse wheel and camshaft, so that the injection timing is retarded.

This kit was certified by EPA letter dated October 21,1998, and described in a Federal Register notice published at 63 FR 66798 on December 3, 1998.

Johnson Matthey submitted life cycle cost information for the CCT kit on January 26, 1999.

The 45-day public review period was started by a Federal Register notice of March 10,1999 (64 FR 11864).

*17. E**ngelhard ETX Rebuild Kit for 1988 - 1993 ~92TA DDFC engines.***

This certified kit is similar to the previously certified ETX kit for MUI engines, and applicable to all federal and California 6V92TA DDEC engines. The kit is designed to update all DDEC engines to either 253 or 277 horsepower. The DDEC version of the ETX kit uses many of the components of the DDC 6V92TA DDECII upgrade kit, along with an exhaust catalyst (CMX 5), proprietary engine coatings on the cylinder head fir e deck and piston crown, and an improved turbocharger. The kit is intended to comply with the 0.10 g/bhp-hr PM standard for less than the life cycle cost limit of $7,940 (in 1992 dollars).
The ETX was certified by EPA letter dated July 1, 1998, and a Federal Register notice was published on December 3, 1998 (63 FR 50223).

This equipment triggers the 0.10 g/bhp-hr standard for 1988 - 1993 model year 6V92TA DDFC II engines.

18. Turbodyne Systems BusPac kit for 1979 - 1989 6\[92TA MUJ engines.

This candidate kit is intended to comply with the Q.10 g/bhp-hr PM standard. The BusPac kit consists of the exhaust catalyst from the 25% reduction kit previously certified by Engine Control Systems (1/6/97) and a TurboPac supercharger system supplied by Turbodyne Systems. The equipment is applicable to DDC 6V-92TA MUI engine models for years 1979 to 1989. The kit requires that the engine be rebuilt to a 1988/89 OE configuration. The notification does not provide any life cycle cost information and does not intend to trigger any standards. This application is currently under EPA review.

19. Detroit Diesel ***Corporation's DDFC kit for the 0.10 g/bhp -hr PM standard.***

This certified kit utilizes components from DDC's certified engine upgrade kit, modified fuel injectors, conversion from DDEC II to DDEC IV engine control system, and a converter/muffler. DDC has submitted emissions data from testing using three catalysts supplied by three different catalyst manufacturers (Nelson, Engelhard, and Engine Control Systems). The equipment is applicable to DDC's 6V-92TA DDEC engine models of model years 1985 through 1993, Federal and California, 253 and 277 horsepower. Applies to diesel and methanol-fueled engines. No life cycle cost information has been supplied. This kit was certified by letter dated October 2,1998.

20. Engelhard Fix Plus kit for 1988-1993 ~92TA DDEC II engines.

This candidate kit utilizes an improved CMX-6 integrated catalytic converter muffler and a coated turbocharger. The other engine components are standard components for a DDC 6V92TA DDEC 111991 - 1993 engine. The CMX-6 is intended to replace the standard muffler in the engine exhaust system. The turbocharger is a standard 6V92 turbocharger modified for improved response and airflow.

21. Johnson Matthey CEM IV catalyst for 4 stroke/cycle engines

22. Johnson Matthey 5

CRT particulate filter applicable to all 2 & 4 stroke/cycle urban bus diesel engines. Would replace the standard exhaust noise muffler. Requires low sulfur diesel fuel having no more than 50 ppm sulfur. Iris self-regenerating (0.10).

23. Biodiesel Development Corporation

Oxidation catalyst, biodiesel additive (20%) and optional injection timing retard.