AN EMISSIONS ANALYSIS OF THE COUNTY AND BI-COUNTY AGENCY FLEETS

Office of Legislative Oversight
Report Number 2003-4

June 24, 2003

Sue Richards
Benjamin Stutz
Scott Brown

EXECUTIVE SUMMARY

The federal Environmental Protection Agency has classified the Washington metropolitan area as a severe nonattainment area for ozone. As a result, federal transportation funds are at risk unless the region develops a plan to address the air quality problem.

Vehicle emissions not only contribute to the area's ozone problem, but also pose a public health risk. High concentrations of ozone cause shortness of breath and an increased risk of cancer. Exposure to particulate matter makes people more susceptible to respiratory illnesses, such as asthma or bronchitis. Children are at a higher risk compared to adults because they breathe more rapidly and inhale more pollution per pound of body weight.

The Council requested this study to provide a better understanding of the fleet emission levels and related management practices of the five County and bi-County agencies. The Council's view, as stated in the forthcoming Montgomery County Environmental Policy, is that government should lead by example even if local agency fleet emissions represent a small part of a complex, regional air quality problem.

Agency fleet emissions data. Using FY 02 data, the Office of Legislative Oversight estimated the emissions of the agencies' vehicle fleets. In sum:

- The five agencies collectively manage a fleet of approximately 6,000 vehicles that annually travel 75 million miles and burn 10 million gallons of fuel;
- In FY 02, this fleet emitted approximately 738 tons of nitrogen oxides, 211 tons of hydrocarbons and 24 tons of particulate matter; and
- Transit buses, school buses and heavy trucks accounted for 95 percent of these emissions.

Buses built before 1991 pollute at significantly higher rates than buses built since 1991. In FY 03 the County Government operates 17 pre-1991 transit buses, and MCPS operates 112 pre-1991 school buses.

Off-road vehicle equipment such as lawn mowers, bulldozers and graders, represent a significant source of emissions. The County's Department of Environmental Protection estimates that off-road equipment emits approximately 20 percent of the ozone forming pollution in the County. Emission standards for this equipment first took effect in 1997. The five agencies own approximately 4,500 pieces of non-road engine equipment and a significant portion of this inventory pre-dates the establishment of the 1997 standards.

Strategies to reduce vehicle emissions. Promising strategies being used across the country to reduce emissions or "green" vehicle fleets include:

- Perform routine preventive maintenance;
- Encourage driving habits that conserve energy, e.g., limit idling;
- Use fuel efficient vehicles;
- Manage size of vehicle fleet;
- Replace older vehicles with more fuel efficient or cleaner burning vehicles;
- Use alternatively fueled vehicles;
- Use diesel fuel additives or ultra-low sulfur diesel fuel; and
- Retrofit existing diesel engines.

The various strategies address different vehicle types; some strategies apply to all types of fleet vehicles and others only apply to buses. The strategies reduce different pollutants as well. Some strategies reduce only one pollutant, e.g., nitrogen oxide, hydrocarbons or particulate matter. Other strategies reduce combinations of pollutants. All strategies would improve public health; however, only the strategies to reduce nitrogen oxides and hydrocarbons would help address the region's ozone problem.

Significant changes in some of the factors that determine vehicle emission rates will occur in the near future. For example, because diesel buses must meet increasingly stricter federal emission standards, the emission benefits of a CNG bus relative to a diesel bus are expected to diminish in model year 2004 and disappear in model year 2007. In addition, beginning in 2006, all diesel vehicles will be required to use ultra low sulfur diesel fuel. The use of ultra low sulfur diesel fuel by itself reduces particulate matter emissions by 25 to 30 percent. The use of an after-treatment device with ultra low sulfur diesel fuel further reduces particulate matter and also reduces volatile organic compound emissions. Retrofit devices currently in development will reduce nitrogen oxide emissions as well.

Current agency practices aimed at reducing vehicle emissions. Some management practices to reduce fleet vehicle emission are already in place. For example, the five County and bi-County agencies comply with the State vehicle inspection program, provide routine preventive maintenance, and limit vehicle use and refueling on Code Red days.

Comparatively, the County Government's fleet includes the largest number of alternatively fueled vehicles. The County owns 24 compressed natural gas (CNG) transit buses, and expects to replace all of its pre-1991 buses later this year with new CNG buses. These new buses will produce six times less nitrogen oxide, three times less hydrocarbon and 56 times less particulate matter than the buses they replace. The County Government has also retrofitted 41 pre-1994 diesel buses with EPA certified engines.

Recommendation for Council action. OLO recommends that the Council engage the agencies in a two-step process to develop an inter-agency action plan. Based upon research into promising practices, OLO identified 11 potential strategies to reduce the emissions of the agency fleets.

As step 1, OLO recommends the Council transmit the list of potential strategies to the five agencies and ask each agency to recommend feasible, cost effective priority projects to reduce vehicle emissions. The Council should ask the agencies to weigh in on whether the Council should be guided by public health concerns, ozone nonattainment issues, or a combination of the two as it sets priorities for the action plan to reduce fleet vehicle emissions. In addition, the Council should ask the agencies to comment on the merits of the additional work that would be needed to incorporate these projects into the regional solution to bring the area into compliance under the Clean Air Act.

As step 2, OLO recommends that the Council review the agencies' responses with the goal of adopting an interagency action plan this fall that outlines priority strategies. At that time, the Council would also need to decide whether and how to integrate its action plan with the regional efforts to address the ozone nonattainment issue.

OLO REPORT 2003-4

AN EMISSIONS ANALYSIS OF THE COUNTY AND BI-COUNTY AGENCY FLEETS

Page #'s

LIST OF EXHIBITS

EXHIBIT #	EXHIBIT TITLE	CIRCLE #

Appendix A: Agency Vehicle Emission Summaries

Montgomery County Government:

Montgomery County Public Schools:

EXHIBIT #	EXHIBIT TITLE	CIRCLE #

Maryland National Capital Park and Planning Commission:

Montgomery College:

EXHIBIT #	**EXHIBIT TITLE**	**CIRCLE #**

Washington Suburban Sanitary Commission:

Methodology:

Glossary of Terms

Carbon Monoxide (CO) is a colorless, odorless, and poisonous gas produced by incomplete burning of carbon in fuels. Major sources include fuel burning equipment (e.g., vehicles and residential heating). Other major sources are wood-burning stoves, incinerators and industrial sources. Nationally, approximately 75 percent of nationwide CO emissions are from transportation sources.

When CO enters the bloodstream, it reduces the delivery of oxygen to the body's organs and tissues. It can cause chest pain in heart patients, headaches, and reduced mental alertness. Health threats are most serious for those who suffer from cardiovascular disease.

Carbon Dioxide (CO_2) is the principal greenhouse gas emitted from burning coal, oil, and natural gas. CO_2 can cause burns, frostbite, and blindness if an area is exposed to it in solid or liquid form. If inhaled, it can be toxic in high concentrations, causing an increase in the breathing rate.

A Catalytic Converter consists of a metal housing filled with a hard material, covered with a catalytic compound. The presence of the catalytic converter in the engine exhaust system breaks down the chemicals and reduces harmful pollutant emissions.

National Ambient Air Quality Standards (NAAQS). The Clean Air Act (1990) requires EPA to set National Ambient Air Quality Standards for pollutants considered harmful to public health and the environment. The Clean Air Act established two types of national air quality standards. Primary standards set limits to protect public health, including the health of "sensitive" populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, damage to animals, crops vegetation, and buildings.

Nitrogen Oxides (NO_X) are a major contributor to smog and acid rain. Under high pressure and temperature conditions in an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides, collectively known as NO_X. NO_X react with volatile organic compounds (VOC) to form smog. In high doses, smog can harm humans by causing breathing difficulty for asthmatics, coughs in children, and general illness of the respiratory system

A Nonattainment Area is a locality where air pollution levels persistently exceed National Ambient Air Quality Standards. Designating a nonattainment area is a formal rulemaking process and EPA normally takes this action only after air quality standards have been exceeded for several consecutive years.

Ozone (O_3) occurs naturally in the upper atmosphere to protect the earth from ultraviolet rays. At ground level, it is a pollutant with highly toxic effects. Ground-level ozone can irritate the respiratory tract, cause chest pain, persistent cough, an inability to take a deep breath. Ozone is formed through complex chemical reactions. Precursor compounds like VOCs and NO_X react to form ozone in the presence of sunlight. These reactions are stimulated by ultraviolet radiation and temperature, so peak ozone levels typically occur during the warmer months.

Particulate Matter (PM) is any type of solid in the air in the form of smoke, dust, and vapors, which can remain suspended for extended periods. Microscopic (less than 10 microns) particles in the air can become lodged in the lung tissue and cause increased respiratory disease and lung damage. PM is also the main source of haze. PM is produced by many sources, including burning of diesel fuels by trucks and buses.

A Particulate Trap is an after-treatment pollution control device that filters or traps diesel particulate matter from engine exhaust until the trap becomes loaded to the point that a regeneration cycle is implemented to burn off the trapped particulate matter.

Retrofit. An engine "retrofit" includes (but is not limited to) any of the following activities:

- Adding new/better pollution control equipment to certified engines;
- Upgrading an uncertified engine to cleaner "certified" configuration;
- Converting any engine to a cleaner fuel;
- Replacing older engines with newer (presumably cleaner) engines ahead of schedule;
- Using cleaner fuel and/or emission reducing fuel additives.

Sources of Air Pollution. Air pollutants are emitted from the following categories of sources:

- **Point and Area Sources** such as, electric utilities and other fuel combustion industrial processes such as, manufacturing, painting and surface coating, metals and chemical processing, dry cleaners.

- **On-road Vehicles** such as, automobiles and motorcycles, light duty trucks (minivans, pickup trucks, sport utility vehicles), heavy duty trucks, and buses.

- **Non-road vehicles, engines, and equipment** such as, lawn and garden equipment, construction equipment, farm equipment, aircraft, boats and other marine vessels, railroad.

- **Miscellaneous sources** such as, forest wildfires and agricultural fires, cooling towers, and windblown dust.

The State Implementation Plan (SIP) is a written plan that describes a State's strategy for achieving and maintaining the National Ambient Air Quality Standards.

The Conformity Rule requires that transportation plans, programs, and projects conform to state air quality implementation plans (SIPs) and establishes the criteria and procedures to determine if plans comply. Conformity to a SIP means that transportation activities will not produce new air quality violations, worsen existing violations, or delay timely attainment of the National Ambient Air Quality Standards.

Transportation Improvement Plan. The Federal Aid Highway Act requires metropolitan planning organizations for each urban region to develop both a long term transportation plan as well as a short term Transportation Improvement Plan (TIP). The Federal Highway Administration must certify this planning process and approve individual projects before it releases federal funds for a specific transportation project.

Unburned Hydrocarbons (HC) represent a general class of gaseous organic compounds. Unburned HCs can react in the presence NO_X and sunlight to form ground-level ozone, a major component of smog. Some HCs are toxic and can potentially cause cancer.

Volatile Organic Compounds (VOC) are organic chemicals that easily vaporize at room temperature. VOCs have no color, smell, or taste. Hydrocarbon VOCs are usually grouped into methane and other non-methane VOCs and are defined by the Clean Air Act as chemicals that participate in forming ozone.

VOCs are emitted from diverse sources, including automobiles, chemical manufacturing facilities, drycleaners, paint shops and other commercial residential sources that use solvent and paint. Many VOCs are hazardous air pollutants; for example benzene causes cancer.

Index of Abbreviations

AFV	Alternative Fueled Vehicle
APTA	American Public Transit Association
CARB	California Air Resources Board
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO2	Carbon Dioxide
CRS	Congressional Research Service
DEP	Department of Environmental Protection (Montgomery County)
DGE	Diesel gallon equivalents
E85	Ethanol
EGR	Exhaust gas recirculation
EPA	Environmental Protection Agency
GVW	Gross Vehicle Weight
ICLEI	International Council for Local Environmental Initiatives
LNG	Liquid Natural Gas
MC	Montgomery College
MCG	Montgomery County Government
MCPS	Montgomery County Public Schools
MECA	Manufacturers of Emission Controls Association
M-NCPPC	Maryland National Capitol Park and Planning Commission
MTA	Massachusetts Turnpike Authority
MY	Model year

NAAQS	National Ambient Air Quality Standards
NLEV	National Low Emission Vehicles
NO_X	Nitrous oxides
PM	Particulate matter
PPM	Parts per million
RFG	Reformulated Gasoline
SCR	Selective catalytic reduction
SIP	State implementation plan
SUV	Sport Utility Vehicle
TIP	Transportation improvement plan
UCS	Union of Concerned Scientists
VOC	Volatile Organic Compound
VMT	Vehicle Miles Traveled
WSSC	Washington Suburban Sanitary Commission

I. Introduction, Purpose, Scope and Organization

The cars and trucks we drive and the equipment we use in our everyday routines emit harmful chemicals. An incomplete fuel combustion process creates pollutants that produce smog, acid rain and global warming. High concentrations of smog, created when volatile organic compounds combine with nitrogen oxide, cause shortness of breath, wheezing and throat and eye irritation. Particulate matter accumulates in the respiratory system and can aggravate health conditions such as asthma.

Purpose and Scope. This study estimates the emissions of the County and bi-County agency vehicle fleets and identifies potential strategies for reducing how much these fleets pollute. Specifically, it includes on-road and off-road vehicle and equipment inventory data, and reports the estimated levels of nitrogen oxide (NO_X), volatile organic compounds (VOC) and particulate matter (PM) produced by the agencies' vehicle fleets. The five agencies are the:

- Montgomery County Government (MCG),
- Montgomery County Public Schools (MCPS),
- Washington Suburban Sanitary Commission (WSSC),
- Maryland-National Capital Park and Planning Commission (M-NCPPC), and
- Montgomery College (MC).

Federal transportation funds for the greater Washington Metropolitan area are at risk, unless the region develops a plan to address the air quality problem. The Council requested this study to provide a better understanding of the fleet emission levels and related management practices of the five County and bi-County agencies. While recognizing that fleet emissions of the five agencies represent one small part of a complex, regional issue, as stated in the forthcoming Montgomery County Environmental Policy, the Council believes it is important for government to lead by example.

Organization. This report is organized as follows:

- Chapter II provides background information about the science of vehicle emissions, the health effects of pollutants, and the Clean Air Act;
- Chapter III provides information on EPA fuel regulations and vehicle emission standards;
- Chapter IV presents the emission inventories for the five County and bi-County fleets;
- Chapter V provides an overview of promising vehicle emission control strategies and reports on the practices the agencies currently use to manage their vehicle emissions;
- Chapter VI presents off-road inventories for the five agencies, and
- Chapters VII and VIII outline OLO's findings and recommendations.

The appendices provide detailed information about each agency's fleet and engine inventories and supplemental information about OLO's methodology and calculations.

Terminology. This report uses many scientific terms and abbreviations. The terms NO_X, VOC and PM refer to three common pollutants: nitrogen oxide, volatile organic compounds and particulate matter. The terms hydrocarbon and volatile organic compound are used interchangeably; hydrocarbons are a subset of volatile organic compounds produced by transportation sources. See the glossary of terms (page viii) for a list of definitions and abbreviations.

Acknowledgements. The Office of Legislative Oversight appreciates the assistance of multiple staff members from the County Government's Department of Public Works and Transportation and Department of Environmental Protection, Montgomery County Public Schools, Washington Suburban Sanitary Commission, Maryland-National Capital Park and Planning Commission, and Montgomery College.

OLO specifically thanks the following agency staff for their contributions: Sharon Subadan, Tom McAllister, Jo Ann Byrum, Jon Kavaliunas, Rodney Martin, Tom Orr, Bill Selby, Phil McLaughlin, Carolyn Biggins, and Mark Gibson from DPWT; John Matthews, Joe Iannuzzi, Mike Vernon, Mike Allnutt, and Johnnie Grimes from MCPS; Al Astorga and Robert Kotter from M-NCPPC; Bill Banwarth and Alan Cartwright from WSSC; and Robert Wirth and Rita Shumaker from Montgomery College.

OLO also greatly appreciates the invaluable technical assistance provided by Mary Richmond and Ann Elsen from Department of Environmental Protection, and Tom Timbario and Tom King from Edwards and Kelcey, Inc.

II. Background

This study reports the emission levels of vehicles operated by the five County and bi-County agencies. It examines these estimates within the broader regulatory context of the Clean Air Act and the Washington metropolitan area's classification as a severe nonattainment area for ozone.

To place the findings of this report in context, this chapter provides background on the health effects of vehicle emissions, and the requirements of the Clean Air Act, including the conformity process, which links air quality planning and transportation planning. It is organized as follows:

- Part A describes types of vehicle emissions,
- Part B reviews the health effects of pollutants,
- Part C explains the building blocks of the Clean Air Act,
- Part D provides information about the air quality in the Washington metropolitan region,
- Part E summarizes the implementation of the Clean Air Act in the Washington metropolitan region, and
- Part F describes the perspectives that shape the public policy discussion about air quality and vehicular pollutants.

A. Types of Vehicle Emissions

Vehicles produce pollution through exhaust and fuel evaporation. Exhaust pollutants are by-products of an incomplete fuel combustion process. Under ideal conditions, gasoline or diesel fuel, which consists of hydrocarbons, combust to form water and carbon dioxide. However, when the combustion process does not completely burn fuel, pollutants are produced in the vehicle's exhaust emissions. The most common exhaust pollutants are hydrocarbons nitrogen oxides, carbon monoxide, and carbon dioxide. Hydrocarbons, nitrogen oxides, carbon monoxide and particulate matter are regulated pollutants and carbon dioxide is a greenhouse gas suspected of contributing to global warming.

Evaporative emissions are produced when fuel escapes into the air through fuel evaporation. On hot days, evaporative losses can account for a majority of the total hydrocarbon pollution. There are different types of evaporative emissions:

- Diurnal emissions occur when the fuel tank heats up and vents gasoline vapors;
- Running loss emissions occur when a hot engine and exhaust system vaporize gasoline when a car is running;
- Hot soak emissions occur after a car is turned off but the engine is still hot; and
- Refueling emissions occur when gasoline vapors are forced out of the fuel tank during refueling.

Air quality planners have developed sophisticated computer models to estimate emissions from each of these sources. The estimates in this report use factors based on a vehicle's age, weight, and mileage. This simplified calculation does not capture the range of emissions found in the more sophisticated models. (See Chapter IV, page 19, for more details about the methodology used in this analysis.)

B. The Health Effects of Pollutants

The combustion of hydrocarbon fuels produces volatile organic compounds, nitrogen dioxide, carbon monoxide, particulate matter, sulfur dioxide, and lead. Many of these pollutants are invisible but not harmless.

- **Volatile Organic Compounds (VOCs) and Nitrogen Oxides (NOx)** react to produce ozone, a major component of smog. High concentrations of ground level ozone occur during hot, sunny days, when the flow of air is limited or stagnant and a mixture of VOCs and NO_x is present.

  Smog can cause shortness of breath, wheezing, and throat and eye irritation. Anyone suffering from a lung disease, such as asthma, pneumonia, emphysema, or even a cold, has more difficulty breathing. Children breathe more rapidly and inhale more pollution per pound of body weight than adults. As a result, they are more at-risk for short and long-term respiratory problems.

- **Particulate matter (PM)** are tiny particles of dust that can become lodged in the lung tissue, causing increased respiratory disease and lung damage. People may experience shortness of breath and may be more susceptible to respiratory illness such as asthma or bronchitis. People with existing heart or lung diseases are at increased risk of premature death when exposed to particulate matter. The incomplete combustion of diesel fuel can produce significant quantities of particulate matter.

- **Carbon monoxide (CO)** is a highly poisonous gas that reduces the delivery of oxygen to the body's organs and tissues. It can cause chest pain in heart patients, headaches, and reduced mental alertness. Health threats are most serious for those who suffer from cardiovascular disease.

- **Carbon dioxide (CO_2)** is a greenhouse gas that traps the earth's heat and is suspected of contributing to global warming.

The health risks from polluted air are highest during the ozone season, which occurs from May through September each year. Exhibit 1, page 5, further summarizes the potential health effects of vehicle emission pollutants.

C. The Building Blocks of the Clean Air Act

Congress initially passed the federal Clean Air Act in 1970, and adopted significant amendments in 1990. This section provides a brief introduction to the key components of the Clean Air Act.

EXHIBIT 1: AIR POLLUTANTS ASSOCIATED WITH VEHICULAR EMISSIONS

Pollutant	Source	Environmental and Health Effects
Hydrocarbons (HC)	Unburned or partially burned fuel	Certain hydrocarbon species are carcinogenic or otherwise toxic. Hydrocarbons are also ozone precursors. With sufficient sunlight, reactive hydrocarbon species react with nitrogen dioxide in the atmosphere to produce ozone (O_3). Methane, the principal hydrocarbon constituent in CNG engine exhaust, is a powerful greenhouse gas.
Carbon monoxide (CO)	Product of incomplete combustion of carbonaceous fuels	Carbon monoxide is hazardous in high concentrations because it binds with hemoglobin in the blood, impairing its ability to transport oxygen.
Carbon dioxide (CO_2)	Product of complete combustion of carbonaceous fuels	Carbon monoxide promotes greenhouse effect by increasing atmospheric absorption of infrared radiation as its concentration in the atmosphere increases.
Nitrogen oxides (NO_X) (includes NO and NO_2)	Reactions between oxygen and nitrogen in air at high temperatures	As emitted directly from the tailpipe, NO_2 consists mainly of NO (90% NO + 10% NO_2). NO is non-toxic and does not promote the formation of ozone. However, NO is rapidly converted to NO_2 in the atmosphere. NO_2 is an oxidizing gas which, in concentrations higher than 0.2 ppm, irritates and damages lung tissue. NO_2 also combines with water to form nitric acid. Deposition of nitric acid is damaging to plants in forests and lakes.
Ozone (O_3)	Reactions between HC oxygen and NO_2 when stimulated by sunlight	Ozone is a strongly oxidizing gas, which is naturally present in the unpolluted atmosphere at a concentration of 0.04 ppm. At concentrations greater than 0.12 ppm, it causes decreased lung function and damages lung tissue. It also damages plants.
Sulfur oxides (SO_X)	Combustion of sulfur in fuel	SO_2 reacts with atmospheric water to form sulfuric acid. Subsequent reactions convert the sulfuric to an extremely fine solid sulfate aerosol, which impairs visibility. Disposition of this acidic material is damaging to plants.
Particulate matter (PM)	Product of combustion in diesel engines. Also produced by tire wear. PM is also produced by conversion of NO_2 and SO_X into aerosols in the atmosphere.	Particulate matter scatters light, reducing visibility. Particulate material finer than 10 microns in diameter (PM10) is absorbed by the lungs and causes lung damage. Diesel particulate consists of PM10, and has been classified as a carcinogen by the California Air Resources Board. Particulate formed by atmospheric processes converting NO_X and SO_X into solid aerosol is considered the major source of acidic deposition (also called "acid rain").

Source: TCRP Report 38, Transportation Research Board, National Research Council.

National Ambient Air Quality Standards (NAAQS). The Clean Air Act requires the Environmental Protection Agency (EPA) to establish standards that define "acceptable" levels of air pollution from a public health perspective. Based on a review of the scientific literature, EPA sets standards for six criteria pollutants: ozone, carbon monoxide, particulate matter, sulfur dioxide, nitrogen dioxide and lead. Exhibit 2 summarizes the six pollutants, their characteristics and their sources.

EXHIBIT 2: CRITERIA AIR POLLUTANTS

Criteria Air Pollutant	Characteristics	Sources
Ozone	Ground level ozone is the major component of smog.	Formed when reactive gases and nitrogen oxides react in presence of sunlight. Any source that burns fuel, such as solvents; petroleum processing and storage; and pesticides.
Carbon Monoxide	Carbon monoxide is a colorless, odorless, poisonous gas.	Any source that burns fuel such as cars, trucks, heavy construction equipment, farming equipment and residential heating.
Particulate matter	Particulate matter is a mixture of solid particles and liquid droplets found in the air.	Road dust, windblown dust, agriculture and construction, fireplaces; fuel combustion in motor vehicles, equipment and industrial sources; residential and agricultural burning; also formed from other pollutants
Sulfur Dioxide		Coal or oil burning power plants and industries, refineries and diesel engines
Nitrogen Dioxide	Nitrogen dioxide is a brownish, highly reactive gas.	Any source that burns fuel such as cars, trucks, heavy construction equipment, farming equipment and residential heating.
Lead	Lead is a widely used metal.	Metal smelters, resource recovery, leaded gasoline, deterioration of lead paint

Source: California ARB Fact Sheet: Air Pollution, Sources, Effects and Control

The Clean Air Act requires EPA to review and reaffirm or modify the NAAQS every five years. In practice, this happens less frequently than required. EPA's most recent review in 1997 resulted in new standards for ozone and particulate matter. Although court challenges have delayed implementation of these new standards, they are currently expected to take effect in 2004.

Attainment and Nonattainment Areas. States must monitor the six criteria pollutants and submit data from air quality monitors annually to EPA. EPA then determines whether a geographic area meets the NAAQS by reviewing these data. An area that meets the standards for each of the six criteria pollutants is classified as an "attainment" area. An area that does not meet the standards is labeled a "nonattainment" area. As of December 2002, two major air pollutants, ozone and particulate matter, are responsible for most nonattainment areas. Specifically:

- 36 areas with a total population of 85.5 million are nonattainment areas for ozone;
- 61 areas with a population of 24.9 million people are nonattainment areas for particulate matter; and
- 36 areas with 18.4 million people are nonattainment areas for carbon monoxide, sulfur dioxide or lead.

When the new standards for ozone and particulate matter take effect in 2004, the number of nonattainment areas is expected to double.

Classifying the Severity of the Air Quality Problem. The 1990 Clean Air Act amendments grouped nonattainment areas into five classes based on the severity of their air quality. Areas were ranked based on readings from air quality monitors for the three years preceding the adoption of the 1990 amendments. The 1990 amendments also established specific controls and deadlines for each class. Deadlines and regulatory actions vary based on the severity of the problem; more severe problems are subject to more stringent requirements, but also given more time to come into compliance. Exhibit 3 shows the classification system for ozone nonattainment areas.

EXHIBIT 3: CLASSIFICATION SYSTEM FOR OZONE NONATTAINMENT AREAS

Class	Deadline	Number of Areas
Marginal	3 years (1993)	42
Moderate	6 years (1996)	32
Serious	9 years (1999)	14
Severe	15-17 years (2005-2007)	9
Extreme	20 years (2010)	1

Source: Congressional Research Service Report RL30022. "Summaries Environmental Laws Administered by the EPA: Clean Air Act."

Sources of Pollution. EPA uses three categories of emission sources to establish regulatory controls and programs to address air pollution.

- **Point and area sources** are stationery sources of emissions such as factories and power plants.
- **Mobile sources** are moving emission sources such as cars, trucks, buses, or construction equipment.
- **Miscellaneous sources** refer to items, such as forest fires, that do not fit into the first two categories.

Within the mobile source category, this report uses the terms "light duty vehicles" and "heavy duty vehicles" as follows:

- Light duty vehicles refer to passenger cars, pickup trucks, passenger vans and sport utility vehicles. The gross vehicle weight limit for a light duty vehicle or truck is 8,500 pounds.

- Heavy duty vehicles refer to large pickups, buses, delivery trucks, recreation vehicles and semi-trucks. These vehicles have a gross vehicle weight of over 8,500 pounds and are equipped with heavy duty engines. This category also includes large sport utility vehicles and passenger vans with a gross vehicle weight between 8,500 and 10,000 pounds.

Exhibit 4, on page 9, provides more details about EPA emission source categories.

Air Pollution Programs and State Implementation Plans (SIPs). The Clean Air Act is jointly implemented by the federal and state governments. Two tiers of EPA programs address air pollution problems:

- **National programs** – Examples of EPA's national programs to address air quality issues include emission standards for new cars, trucks and other mobile sources, acid rain programs, regional haze programs, and emission standards for hazardous pollutants.

- **State programs** – If an area is in nonattainment, the Clean Air Act allows a state to determine which measures should be imposed to bring an area into compliance. A state must submit a State Implementation Plan (SIP) to the EPA that establishes detailed restrictions for different pollution sources. The SIP must contain sufficient reductions in emissions to demonstrate compliance, using air quality models approved by EPA.

A SIP might include a requirement to burn cleaner, reformulated gasoline; a requirement to operate an automobile inspection and maintenance program; or a requirement that new sources of pollution "offset" their impacts from reductions in other sources of pollution. A SIP also establishes a specific motor vehicle emissions budget (MVEB) that caps emissions from transportation sources.

EXHIBIT 4: DEFINITIONS AND EXAMPLES FOR EPA EMISSION SOURCE CATEGORIES

<table>
<tr><td>Point and Area Sources</td><td>Electric utilities and other fuel combustion industrial processes. Includes manufacturing, painting and surface coating, metals and chemical processing, dry cleaning.</td></tr>
<tr><td>Misc. Sources</td><td>Includes forest and wildfires, health services, cooling towers and windblown dust.</td></tr>
<tr><td>Mobile Sources</td><td>Vehicles, engines and equipment that move or can be moved from place to place.

• On-Road Vehicles - Vehicles and motorcycles used for transportation on the road. They may be fueled with gasoline, diesel fuel or an alternative fuel.

o Light duty vehicles are passenger cars. The term light duty trucks refer to pickup trucks, passenger vans, and sport utility vehicles. The gross vehicle weight limit for a light duty vehicle or truck is 8,500 pounds.

o Heavy duty vehicles include large pickups, buses, delivery trucks, recreational vehicles (RVs) and semi trucks. These vehicles have a gross vehicle weight over 8,500 pounds and are equipped with heavy duty engines. This category also includes large sport utility vehicles and passenger vans with a gross vehicle weight between 8,500 and 10,000 pounds.

o Motorcycles – 2 or 3 wheeled designed for on-road use.

• Off-Road Vehicles, Equipment and Engines – Equipment and vehicles fueled with gasoline or diesel that are used off-road.

° Construction equipment and vehicles – Examples are asphalt and concrete pavers, tampers, rollers, scrapers, excavators, saws. cement mixers, rubber tired loaders, bulldozers, and forklifts.

° Industrial equipment – Examples are aerial lifts, forklifts, sweepers and scrubbers.

° Lawn and garden equipment – Examples include lawnmowers, chainsaws, chippers, chainsaws, snowblowers and weed trimmers.

° Farm equipment – Examples include two wheel tractors, mowers, combines, spayers, balers and tillers.

° Commercial equipment - Generator sets, pumps, air compressors, gas compressors, welders and pressure washers.</td></tr>
</table>

Source: EPA

The Conformity Process. The 1990 amendments to the Clean Air Act created a conformity process to link air quality planning and transportation planning. The Clean Air Act requires that nonattainment areas conduct an air quality planning process and produce a SIP every three years to demonstrate how a nonattainment area will be brought into attainment.

The Federal Aid Highway Act requires metropolitan planning organizations for each urban region to develop a long-term transportation plan as well as a short-term Transportation Improvement Plan (TIP). The Federal Highway Administration must certify this planning process and approve individual projects before it can release federal funds for a specific transportation project.

The Clean Air Act integrates these two planning processes by comparing the emissions predicted from the TIP with the emissions budgeted in the motor vehicle emissions budget established in the SIP.

- If the emissions match, the TIP conforms to the SIP and individual projects in the TIP can receive federal funding.

- If the emission forecast and ceiling do not match, an area experiences a conformity lapse.

Currently, there are more than 266 multi-county areas of the country that must demonstrate conformity.

An October 1999 memorandum from the Congressional Research Service (CRS) reported that, since 1993, 29 states experienced a conformity lapse. Areas often wait until their next revision of the TIP or the SIP to revise projects or institute other measures to return to conformity.

Various penalties exist for not complying with transportation conformity. The EPA can "bump" a region into the next level of nonattainment and the Department of Transportation (USDOT) can withhold federal highway fund projects. USDOT reports there are currently seven metropolitan areas where highway projects are stalled because they have failed to achieve conformity. Many of these projects had been grandfathered under the now invalidated rules.

Sanctions. The Clean Air Act requires the EPA Administrator to impose highway fund and other sanctions on nonattainment areas that have not submitted or implemented adequate plans to meet air quality standards. EPA must formally notify a state of its determination that it has either failed to submit an acceptable plan or failed to implement an approved plan. This notification starts a "sanctions clock;" a state has 18 months to resubmit a plan and correct the deficiency identified by EPA. If the deficiency is not corrected, the law authorizes two types of sanctions:

- The imposition of a 2:1 offset on new or modified sources of emissions; and
- Withholding of certain federal highway funds.

Under the regulations, EPA will first impose the offset sanction. If the deficiency has not been corrected within six months, then both sanctions will be applied.

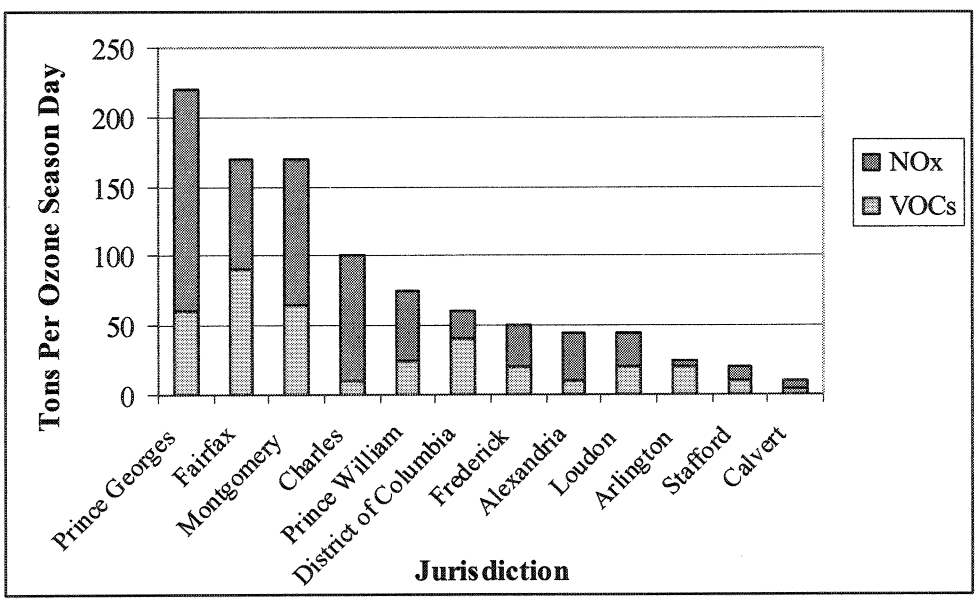
CRS reports, as of October 1999, EPA had made formal findings of non-submittal or incompleteness or disapproval of SIPs 858 times and imposed sanctions in only 18 of these cases. In all 18 cases, EPA imposed the offset sanction; in two cases, EPA also imposed the highway fund sanction.

D. Air Quality in the Washington Metropolitan Region

The quality of air in the Washington metropolitan region is rated as one of the most polluted in the nation. The region's 3.9 million residents face a cancer risk more than 100 times the goal set by the Clean Air Act. According to the American Lung Association (2002), 43 percent of Montgomery County's population, including children, elderly citizens, and people with asthma, bronchitis, and emphysema, face even higher risks.

Montgomery County ranks among the ten percent of counties in the nation with the highest levels of ozone forming pollutants.[2] Exhibit 5 shows emission sources in Montgomery County contribute significantly to the region's ozone problem.

EXHIBIT 5: OZONE EMISSIONS BY JURISDICTIONS IN THE WASHINGTON METROPOLITAN REGION



Source: Montgomery County DEP

[2] Environmental Defense Scorecard, www.scorecard.org

E. Implementation of the Clean Air Act in the Washington Metropolitan Region

The 1990 amendments to the Clean Air Act classified the Washington metropolitan region as a serious nonattainment area for ozone and set a deadline of 1999 for the area to come into compliance. The region failed to meet this 1999 deadline. EPA, recognizing that this failure was largely due to ozone blown in from outside the region, granted an extension to 2005. In January 2001, EPA approved State Implementation Plans submitted by Maryland, Virginia and the District of Columbia with an attainment date of 2005.

In July 2002, the U.S. Court of Appeals vacated EPA's approval of the SIP and ruled that EPA could not grant an extension unless it also reclassified the region as "severe." In January 2003, EPA reclassified the Washington metropolitan region from a serious to a severe nonattainment area for ozone in response to the court ruling. By March 1, 2004, Maryland, Virginia, and the District of Columbia must submit revised State Implementation Plans that address the requirements of a severe nonattainment area.

The Metropolitan Washington Council of Governments (COG) recently released a draft of the "severe" area SIP for public comment. Three elements of this draft SIP address the issue of emission reduction strategies.

> **Rate of Progress Plans and Control Measures.** As a consequence of reclassification to a severe non-attainment area, the Washington region is required to demonstrate continued reductions of three percent per year in NO_X or VOC from 1999 until 2002 and from 2002 until the region reaches attainment in 2005. As part of the SIP process, each nonattainment area submits a three-year plan with control measures to show how it will reduce emissions during the next three years. These plans are called "Rate of Progress" plans. Because the Washington region was not required to submit a plan for the years 1999-2002, the new SIP needs to include two rate-of-progress demonstrations: one for 1999-2002, and one for 2002-2005.
>
> The region's draft SIP for VOC is 30 tons short of the VOC reductions needed to meet the region's rate of progress requirements for 2002. COG is currently developing additional control measures to make up the 30 ton shortfall. Once approved, the SIP and the control measures will be enforceable by state and federal law.
>
> **Contingency Measures**. The SIP must identify a set of contingency measures that will be available in the event the control measures do not bring the area into compliance by 2005. The draft SIP includes a set of contingency measures, which are going through the public hearing process. The contingency measures must be established by January 2004.

The Mobile Emissions Budget. The SIP process establishes a mobile emissions budget as a means to control mobile source pollutants. In the draft SIP, the region's mobile source emission budget (or the maximum allowable level) for 2005 is 98.1 tons per day of VOC and 237.4 tons per day of NO_X. This budget will be the benchmark used to determine if the region's Consolidated Long-Range Transportation Plan (CLRP) and the six-year Transportation Improvement Plan (TIP) conform with the Clean Air Act requirements. If the analysis due in January 2004 does not show conformity, additional emission reduction strategies must be identified to meet the mobile sources emission budget.

F. Air Quality in Context

This background chapter suggests that several perspectives shape the public policy discussion about air quality and vehicular pollutants. From a public health perspective, all pollutants are harmful and affect the quality of air that we breathe. Strategies to reduce the emission of any pollutant will improve public health. From a transportation conformity and highway funding perspective, two specific pollutants, i.e., volatile organic compounds and nitrogen oxides, are cause for concern. Strategies to reduce these two pollutants will help bring the region into attainment with the Clean Air Act. Exhibit 6 summarizes the policy perspectives of vehicle emissions.

EXHIBIT 6: THE POLICY PERSPECTIVES OF VEHICLE EMISSIONS

Common Pollutants	Does the pollutant affect public health and the environment?	Are vehicles a source of pollutant?	Does EPA identify pollutant as a criteria air pollutant?	What is the attainment status for Wash. D.C. area
Volatile Organic Compounds	Yes	Yes	No*	Nonattainment
Nitrogen Oxides	Yes	Yes	Yes	Nonattainment
Ozone	Yes	Yes	Yes	Nonattainment
Particulate Matter	Yes	Yes	Yes	Attainment
Carbon Monoxide	Yes	Yes	Yes	Attainment
Carbon Dioxide	Yes	Yes	No	Not applicable
Sulfur Dioxide	Yes	Yes	Yes	Attainment
Lead	Yes	No**	Yes	Attainment

Source: Montgomery County DEP and OLO

* However, VOCs are a precursor to ozone (see page 4 for details).
** EPA regulations have phased out lead content in fuel since the 1970's.

III. EPA Fuel Regulations and Vehicle Emission Standards

The Clean Air Act authorizes the Environmental Protection Agency (EPA) to regulate fuel and establish vehicle emission standards to control pollution from mobile sources. The adoption of progressively tighter emission standards for different vehicle types has been an effective strategy to reduce vehicle emissions, particularly when vehicles are replaced on a regular basis.

EPA's initial efforts during the 1960's focused on passenger vehicles (with gasoline engines) because they were considered the greatest contributor to transportation pollution. Over time, as EPA's standards took effect, the emissions from passenger vehicles declined and the share of pollution from diesel engines increased. More recently, EPA has begun to target diesel engine emissions.

This chapter presents a brief history of EPA's fuel regulations and vehicle emission standards:

- Part A summarizes EPA fuel regulations,
- Part B presents emission standards for passenger vehicles and light trucks, and
- Part C provides emission standards for heavy duty vehicles, including transit and school buses.

The emission standards discussed in Parts B and C are important because they provide the basis for the emission calculations. See the discussion of the methodology on page 19 and the chart in Appendix N, © 123 for a clearer understanding of the dramatic changes in emission standards over the last thirty years.

A. Fuel Regulation

EPA has regulated fuel since the 1970's when it issued standards to phase out the lead content in gasoline. Since that time, EPA has proposed several programs, some national in scope and others targeted to areas with specific pollution problems. Exhibit 7 shows key milestones in EPA's regulation of fuel.

EPA's most recent regulations will require refineries to reduce the sulfur content in gasoline and diesel fuel. Regulations to reduce the sulfur content in gasoline will be phased in between 2004 and 2006. Regulations to reduce the sulfur content in diesel fuel to 15 parts per million (ppm) will be phased in between 2006 and 2010.

EPA and industry experts estimate the new diesel fuel regulation will increase the cost of fuel by five to ten cents per gallon. The American Public Transit Association (APTA) has questioned whether the use of ultra low sulfur diesel fuel could reduce the expected service life of older transit engines.

EXHIBIT 7: EPA FUEL REGULATION MILESTONES

1973	EPA issues standards to phase out lead content in gasoline.
1989	EPA requires gasoline to decrease evaporative emissions during summer months.
1990	EPA begins oxygenated fuels program in select areas where wintertime carbon monoxide pollution is caused by people starting their cars in cold climates.
1993	EPA limits the maximum sulfur content in diesel fuel by 80 percent to help buses and trucks meet emission standards.
1995	EPA institutes a reformulated gasoline (RFG) program to reduce the emissions of smog forming and toxic pollutants in areas that violate air quality standards. Gasoline refiners must reformulate gasoline sold in these areas to contain less volatile organic compounds (VOCs). EPA estimates the reformulated gasoline will reduce the emissions of hyrdrocarbons by 15 percent in 1995, increasing to 25 to 30 percent by 2000.
2004-2006	EPA regulations to reduce the sulfur content in gasoline will be phased in. The current sulfur level in gasoline averages 347 parts per million (ppm). By 2006, refiners and importers will have to meet an average sulfur level of 30 ppm with a maximum cap of 80 ppm in any gallon.
2006	Beginning June 1, refiners must produce diesel fuel for highway vehicles with a sulfur content of no more than 15 ppm. Currently, the sulfur content of diesel fuel is approximately 350 to 500 ppm. This requirement for ultra low sulfur fuel will increase the cost of fuel by five to ten cents per gallon.

Source: EPA, OLO.

B. Emission Standards for Light Duty Fleets

The typical car on the road today emits pollutants at half the rate of a car on the road in the mid-1960's. Much of this progress is due to emission standards established by EPA and California.

Over the last 30 years, EPA adopted progressively tighter emission standards. In the fall of 2003, new Tier 2 emission standards will be phased in. Under these standards, light vehicles, including all passenger cars, SUV, and most vans and pickups will be held to the same emission standards by model year (MY) 2009. EPA broadened the light vehicle emission standards to incorporate light trucks because they represent an increasing market share. In 2001, light trucks made up 50.8 percent of the new automobile market, compared to 19.9 percent in 1980. Exhibit 8 highlights the key milestones in EPA's regulation of light duty fleets.

EXHIBIT 8: EPA MILESTONES IN EMISSION REGULATIONS FOR LIGHT DUTY FLEETS

1974	EPA creates a separate classification for light trucks in response to a court ruling that concludes they should be classified differently in recognition of their agricultural and commercial uses.
1981	New cars meet standards established in 1970 Clean Air Act for the first time. These standards require a 90 percent reduction in emissions.
1994	Tighter Tier I emission standards required in the 1990 amendments to the Clean Air Act, take effect. Overall, the standards for light trucks are generally less stringent than those for passenger cars. Under these standards, *compact* SUVs and pickups must meet the same standards as passenger cars. Other light trucks are allowed to emit higher levels of pollution with each heavier weight class. As a result, most SUVs and pickups are allowed to emit 29 percent to 47 percent more carbon monoxide and 75 percent to 175 percent more nitrogen oxides than passenger cars.
1998	The federal government and auto manufacturers sign a voluntary agreement to manufacture cars with emission levels lower than the Tier I standards referred to as National Low Emission Vehicles (NLEV).
1999	NLEVs are available in Maryland, Virginia, Washington, DC, Pennsylvania, Connecticut, Delaware, New Hampshire, New Jersey and Rhode Island.
2003-2008	Tier 2 emission standards are scheduled to take effect for Model Year 2004 vehicles. Under these standards, all light vehicles, including all passenger cars and SUVs and most vans and pickups will be held to the same emission standards by MY 2009. These standards also require vehicles to meet the same standards, regardless of fuel type.

Source: EPA, OLO.

C. Emission Standards for Diesel Engines

Compared to gasoline powered engines, diesel engines produce smaller volumes of carbon monoxide and hydrocarbons. However, diesel engines also emit relatively high levels of nitrogen oxide and particulate matter.

In 2000, EPA tightened the regulation of heavy duty diesel engines in order to control the emissions of particulate matter and nitrogen oxides. In MY 2004, new engines must meet standards that reduce nitrogen oxide emissions by 50 percent. In MY 2007, new engines must meet even tighter standards that require an additional 90 percent reduction below the 2004 standards as well as a 90 percent reduction in particulate matter.

In 2000, the California Air Resources Board adopted new urban bus standards that require transit operators to choose between a diesel fuel path or an alternative fuel path for future bus procurements. This rule, which has multiple provisions, requires:

- The use of ultra low sulfur diesel fuel, beginning in July 2002;
- The retrofit of all pre-2004 diesel buses with particulate filters beginning in 2003 through 2007; and
- 15 percent of new bus purchases to be zero emission buses, beginning in 2008.

EXHIBIT 9: EPA MILESTONES FOR THE REGULATION OF HEAVY DUTY DIESEL ENGINES

October 2002	Engines which meet the EPA standards for MY 2004 will be available 15 months early as a result of a 1998 court settlement between the manufacturers and the EPA, the Department of Justice, and the California Air Resources Board.
Fall 2003	EPA rules for heavy duty vehicles are scheduled to take effect in MY 2004. These standards reduce nitrogen oxide emissions by 50 percent and also require all heavy duty vehicles under 14,000 gross vehicle weight (GVW) to have on-board diagnostic equipment to monitor emission control devices.
Fall 2006 - 2009	EPA heavy duty engine standards are scheduled to take effect in MY 2007. These standards, which reduce nitrogen oxide (NO_X) emissions by 90 percent from the MY 2004 standards, will be phased in between 2007 and 2010. The standards to reduce particulate emissions by 90 percent will take full effect in 2007.

Source: EPA, OLO.

IV. Emission Inventories for the Five County/Bi-County Agencies

A. Introduction

An emission inventory reports the sources and amounts of air pollutants for a defined geographic area or a defined set of vehicles. A vehicle emission inventory serves several useful purposes. It provides a snapshot of the amount and types of pollutants produced by a set of vehicles at a given point in time. It identifies large sources of pollutants and it strategically guides the development of programs and resources to reduce emissions. If an inventory is recalculated periodically, an agency can report trends and monitor the success of its emission control strategies over time. Many types of emission inventories exist.

- EPA prepares national emission inventories by pollution source to monitor air quality trends. These inventories report actual air quality monitoring data or estimates and forecasts based on computer modeling.

- Metropolitan planning organizations produce regional emission inventories, emission forecasts and emission budgets as part of their participation in the state implementation plan and air quality planning.

- Businesses and local governments prepare corporate fleet emission inventories to monitor compliance with existing or proposed regulations. For example, the Cities for Climate Protection program helps local jurisdictions conduct inventories of greenhouse gas emissions in order to set proposed emission reduction targets.[1]

B. The Scope of the Inventory

This chapter presents an emission inventory for the vehicles, or mobile (on-road)[2] sources of pollution, owned by the five County and bi-County agencies. The agencies are the:

- Montgomery County Government (MCG),
- Montgomery County Schools (MCPS),
- Washington Suburban Sanitary Commission (WSSC),
- Maryland National Capital Park and Planning Commission (M-NCPPC), and
- Montgomery College (MC).

[1] Montgomery County joined the Cities for Climate Protection Program in July 2000 and agreed to complete the six step program. The steps require the County to: 1) conduct a greenhouse gas inventory; 2) set emission reduction targets, 3) develop an action plan; 4) implement policies and measures to reduce emissions; and 5) monitor and verify results. The County completed its inventory of greenhouse gas emissions in January 2003 and is moving ahead to adopt target reductions.

[2] EPA's classification of Mobile Service On-Road Vehicles includes light duty vehicles, heavy duty vehicles and motorcycles.

The inventory reports the amounts of hydrocarbons, nitrogen oxide and particulate matter produced by the agencies' vehicles and identifies the vehicles that are the major sources of pollution. Staff can use this information to decide how to manage or reduce the emissions of the five agency fleets. Since this inventory examines only the vehicles owned by the five agencies, it represents a much smaller universe than an emission inventory that reports the pollutants for a geographic region.

The inventory reports emission levels for three pollutants:

- hydrocarbons or volatile organic compounds (VOC);
- nitrogen oxides (NO_X); and
- particulate matter (PM).

OLO selected hydrocarbons and nitrogen oxides, which are precursors to smog, because of Montgomery County's status as a severe nonattainment area for ozone. OLO chose to report particulate matter due to recent concerns about the health effects of particulate matter pollution and the high levels of particulate matter pollution from heavy diesel equipment.

This inventory reports only direct emissions from sources owned and operated by the five county and bi-county agencies. It does not include emissions from services which are provided using vehicles owned by contractors or other third party entities, such as trash trucks.

C. Methodology

OLO used data provided by the five agencies and emission factors provided by the consulting firm of Edwards and Kelcey, Inc. to develop the emission estimates presented in the following pages.

To calculate the emissions for an agency vehicle fleet, OLO created a data set that identified the vehicle class (weight), model year, FY 02 mileage, fuel type, and consumption for each vehicle. Next, OLO multiplied the actual FY 02 mileage for each vehicle by an emission factor that was based on the vehicle type, model year and fuel type. OLO calculated the emissions for each of the three pollutants separately. Since these estimates are based on vehicle mileage, they **do not** take into account pollution from idling[3].

The agencies' ability to provide the necessary data varied as did the completeness and accuracy of the data provided. In some cases, agencies were able to provide annual mileage and fuel consumption for individual vehicles. If this data was not available OLO created an annual mileage estimate for each vehicle based on lifetime mileage data

[3] The transit bus estimates are based on bus information provided by MCG during the study. They do not reflect final adjustments made to reconcile FMS and Transit Services data. The particulate matter estimates also do not reflect retrofits to 41 of the pre-1994 buses.

and the model year.[4] OLO also purged the agency fleet data to remove vehicles that were not in service or vehicles that were missing mileage data which could not be estimated. See Appendix A, ©26 for an explanation of these adjustments.

The emission factors provided by the consulting firm of Edwards and Kelcey, Inc. are a set of vehicle pollution rates reported in grams per mile. The rates take into account the differences in vehicle class, e.g., passenger car, light truck, heavy truck, transit bus, school bus, the model year, and fuel type that affect emission levels. The rates represent a simplified approach to the science of emission estimating, in contrast to the complex sets of emission factors used in computer modeling programs. This means that the tons of pollutants reported on the following pages are useful only as relative order of magnitude estimates. The results **cannot be used** to calculate emission credits for state implementation plans. See Appendix A, ©27 for charts of these factors that show how these emission factors vary over time by vehicle type, model year, and fuel type.

The remainder of this chapter is organized as follows:

- **Part D** summarizes the composition and characteristics of the on-road fleet owned by the five County/bi-County agencies.

- **Part E** reports the amount of pollution by vehicle class, e.g. passenger cars, light trucks, heavy trucks, transit buses and school buses and identifies the heaviest polluters.

- **Part F** examines the relationship between vehicle size and pollution rates.

- **Part G** shows the relationship between fleet make up, mileage and pollution.

- **Part H** identifies the inventory's pre-1994 vehicles and discusses the amount of pollution emitted by these vehicles.

- **Part I** provides a comparison of the transit and school bus fleet. It also provides one-page summaries of the composition and characteristics of each agency's FY 02 on-road car and truck fleet. Appendix A (beginning at ©1) contains an in-depth review of each agency's on-road car and truck fleet.

---

[4] OLO's emission calculations exclude twelve gasoline powered mini-buses, three trolleys, and 36 motorcycles because OLO did not have emission factors for these vehicles.

D. Overview of On-Road Vehicle Fleets

In this report, references to the agencies' fleets include only those vehicles that had mileage recorded and emission factors. In FY 02, the agencies maintained 6,045 vehicles. OLO mileage totals and emission estimates are based on 5,926 of these vehicles. See Appendix A, ©26 for more details.

In FY 02, the five County and bi-County agencies 5,926 vehicles traveled 76.2 million miles, and emitted 738 tons of nitrogen oxides, 211 tons of volatile organic compounds, and 24 tons of particulate matter. (See Exhibit 1, page 5 for details about how these pollutants affect air quality and human health.) Exhibit 10 shows the number vehicles and pollutants emitted by each agency. In sum:

- The MCG fleet had 1,506 passenger cars, 589 heavy trucks, 389 light trucks, and 322 transit buses. These 2,806 vehicles traveled 41.3 million miles and emitted 506 tons of pollution.

- MCPS fleet had 1,113 school buses, 243 light trucks, 221 heavy trucks, and 100 passenger cars. These 1,677 vehicles traveled 22.1 million miles and emitted 403 tons of pollution.

- The WSSC fleet had 871 vehicles, including 568 light trucks, 181 heavy trucks, and 122 passenger cars. These vehicles traveled 8.0 million miles and emitted 31 tons of pollution.

- The M-NCPPC fleet had 528 vehicles, including 198 light trucks, 176 heavy trucks, and 154 passenger cars. These vehicles traveled 4.6 million miles and emitted 31 tons of pollution.

- Montgomery College's on-road fleet of 44 vehicles traveled 185,000 miles and emitted two tons of pollutants.

EXHIBIT 10: AGENCY ON-ROAD FLEET COMPOSITION AND CHARACTERISTICS

Agency	# of Vehicles	# of Vehicle Miles Traveled	# of Pollutants (Tons)		
			NOx	VOC	PM
MCG	2,806	41.3	384.5	110.5	11.5
MCPS	1,677	22.1	308	85	10.5
WSSC	871	8.0	21	8	1.5
M-NCPPC	528	4.6	23.5	6.5	1
MC	44	0.2	1	.5	-
Total	**5,926**	**76.2 Million**	**738**	**210.5**	**24.5**

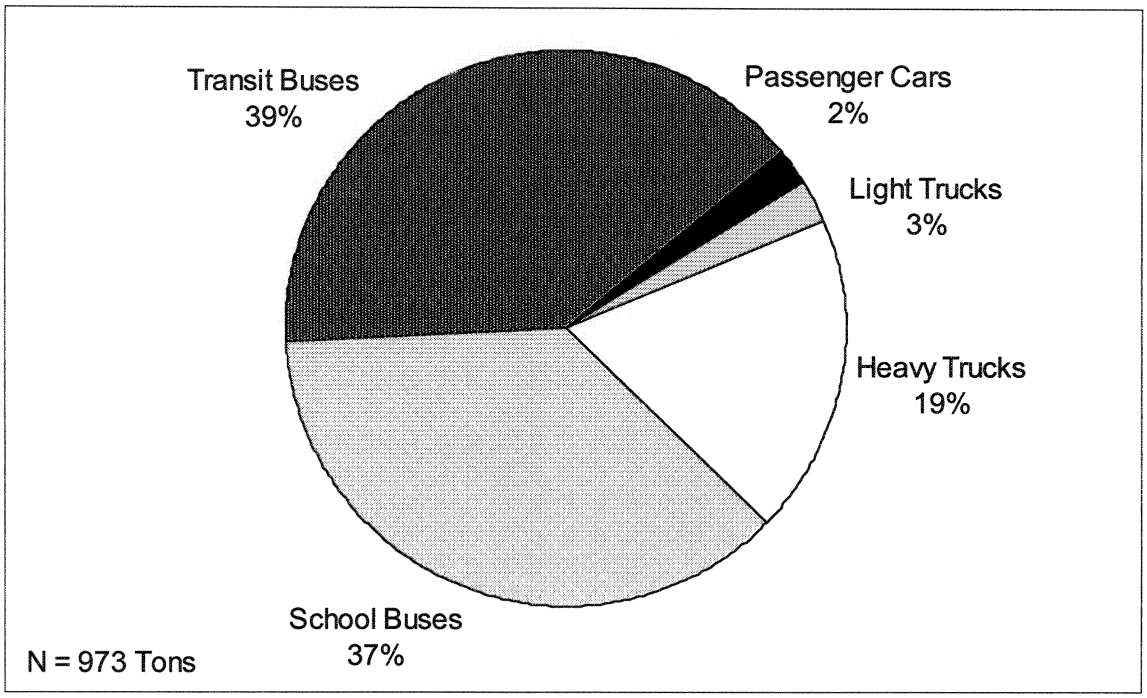
Source: OLO, May 2003

E. Pollution Emitted by Vehicle Class

Transit buses, school buses, and heavy trucks emit 95 percent of all pollutants. The inventory's passenger cars and light trucks (including SUVs) emit the remaining five percent. In FY 02:

- 322 transit buses traveled 13.4 million miles and emitted 387 tons of pollutants, or 39 percent of all emissions.
- 1,113 school buses traveled 18.7 million miles and emitted 358 tons of pollution, or 37 percent of all emissions.
- 1,188 heavy trucks traveled 7.2 million miles and emitted 182 tons of pollutants, or 19 percent of all emissions.
- 3,303 passenger cars and light trucks (including SUVs) traveled 36.9 million miles and emitted 46 tons of pollution, or five percent of all emissions.

EXHIBIT 11: PERCENT OF POLLUTANTS BY VEHICLE TYPE



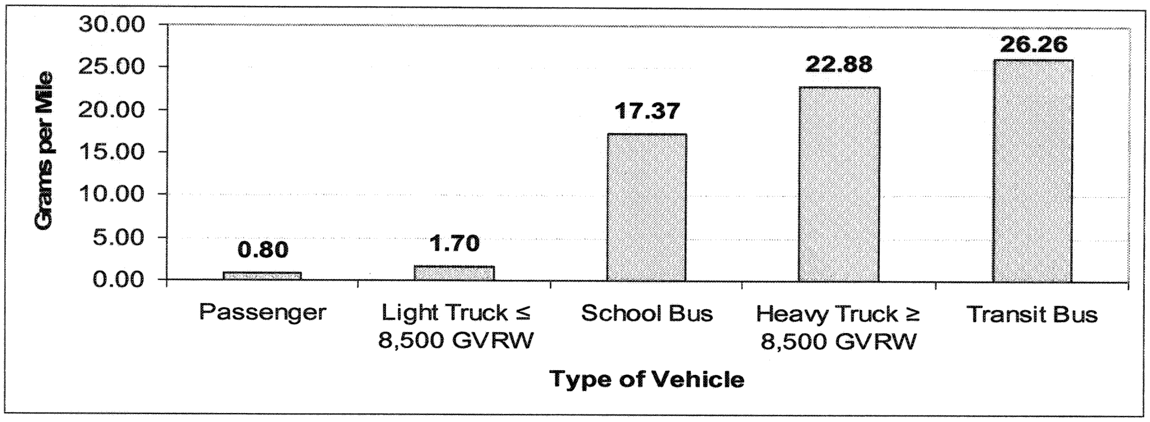
Source: OLO, May 2003

F. The Relationship between Vehicle Size and Pollution Rates

Larger, heavier vehicles pollute at a higher rate than smaller vehicles. For example, based on FY 02 mileages and emissions across the five agency fleets:

- A transit bus emits 26.26 grams per mile,
- Heavy trucks emit 22.88 grams per mile,
- Diesel school buses emit 17.37 grams per mile, and
- Light trucks emit 1.7 grams per mile, or twice the rate of a passenger car.

EXHIBIT 12: AVERAGE RATE OF POLLUTANTS FOR THE COUNTY AND BI-COUNTY FLEET VEHICLES IN FY 02



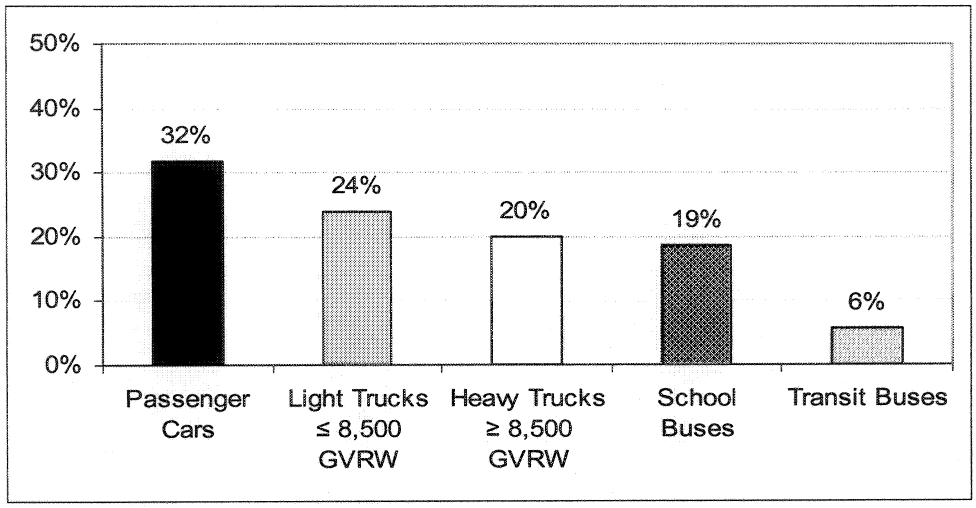
Source: OLO, May 2003

G. Share of Fleet, Vehicles Miles Traveled and Emissions

Exhibits 13-15 on the next page show the relationships among the make up of the fleet, the distribution of mileage by vehicle type, and emissions by vehicle type. The exhibit shows passenger cars and light trucks account for a larger share of the fleet and total mileage, but a smaller share of emissions. In contrast, transit buses, school buses and heavy trucks represent a smaller portion of the fleet and the total mileage, but are responsible for a larger share of emissions. Specifically,

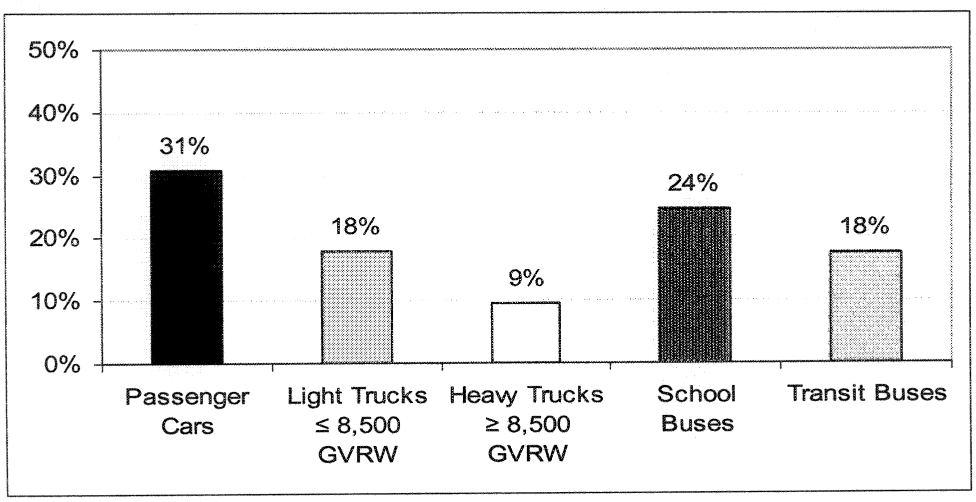
- Transit buses emitted 39 percent of pollutants but accounted for only 18 percent of the fleet mileage in FY 02.
- School buses emitted 37 percent of pollutants but accounted for only 25 percent of the fleet mileage in FY 02.
- Heavy trucks emitted 19 percent of pollutants but accounted for nine percent of the fleet mileage in FY 02.
- Passenger cars and light trucks emitted 5 percent of pollutants but accounted for 49 percent of the fleet mileage in FY 02.

EXHIBIT 13: PERCENT OF FLEET BY VEHICLE TYPE – FY 02



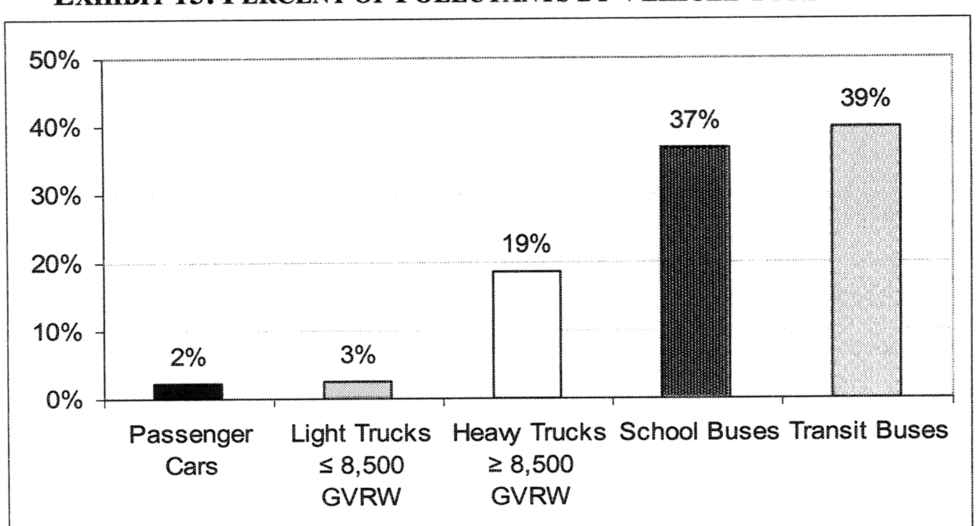
Source: OLO, May 2003

EXHIBIT 14: PERCENT OF VEHICLE MILES TRAVELED BY VEHICLE TYPE– FY 02



Source: OLO, May 2003

EXHIBIT 15: PERCENT OF POLLUTANTS BY VEHICLE TYPE– FY 02



Source: OLO, May 2003

H. Pre-1994 Vehicles

By 1994, tighter EPA emission standards significantly reduced the amount of pollution from all classes of vehicles: passenger cars, light trucks, heavy trucks, transit buses and school buses. Pre-1994 vehicles, especially heavy trucks, transit buses, and school buses, pollute at much higher rates than later model vehicles.

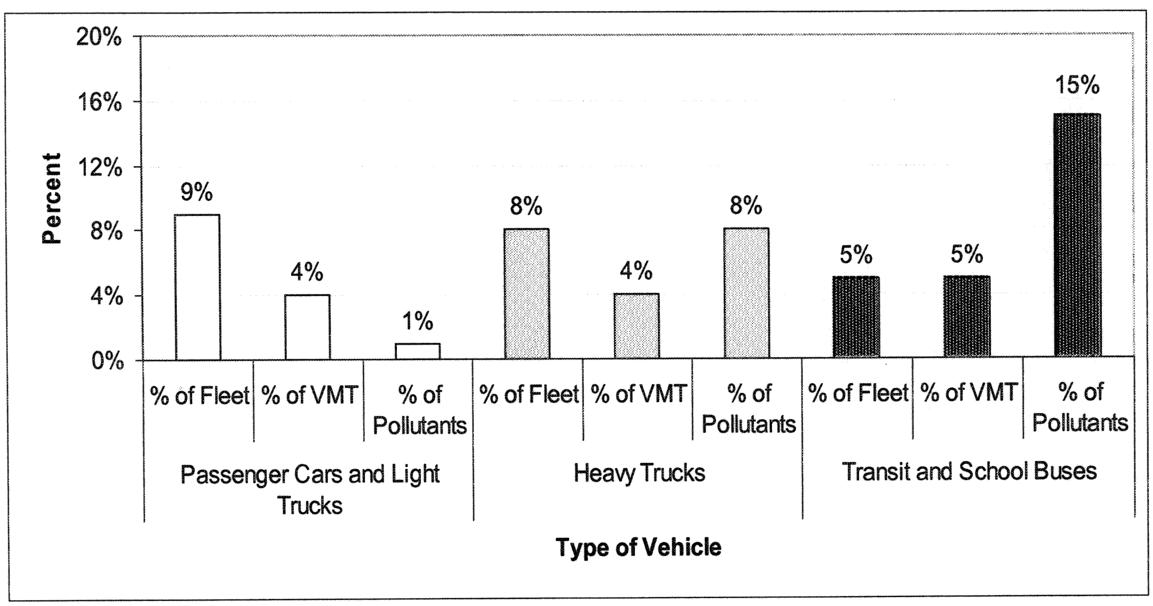
MCPS owns the highest number of pre-1994 vehicles: 262 school buses, 123 heavy trucks, 157 light trucks, and 29 passenger cars. MCG owns the second highest number of pre-1994 vehicles, including 65 transit buses, 217 heavy trucks, 57 light trucks, and 55 passenger cars.

There are 1,361 pre-1994 vehicles across all agencies. They emitted 24 percent of all pollution although they accounted for only 13 percent of the total mileage. Specifically:

- Pre-1994 transit and school buses emitted 15 percent of all pollution but traveled only five percent of the total mileage.

- Pre-1994 heavy trucks emitted eight percent of all pollutants but accounted for only four percent of the total mileage.

EXHIBIT 16: CONTRIBUTION OF PRE-1994 VEHICLES – FY 02



Source: OLO May, 2003

I. Summaries of the Agencies' On-Road Vehicles

This section provides a comparison of the transit and school bus fleet and one-page summaries of the composition and characteristics of each agency's FY 02 on-road car and truck fleet. The summaries are listed as follows:

Appendix A (beginning at ©1) contains an in-depth review of each agency's on-road car and truck fleet. The appendices include:

- Emission rates per mile by vehicle type,
- Average amounts of pollutants by vehicle type taking into account FY 02 mileage,
- The pollutants of pre-1994 vehicles as a percent of total fleet pollutants, and
- The relationship between a specific pollutant and vehicle miles traveled by vehicle type.

The appendices are listed as follows:

In addition, Chapter VI (page 50) provides a summary of the agencies' inventory of off-road equipment.

MCG TRANSIT AND MCPS SCHOOL BUS FLEETS

In FY 02, 1,435 transit and school buses traveled over 32.1 million miles, used 6.3 million gallons of fuel (diesel and compressed natural gas), operated at an overall fuel efficiency of 5.1 miles per gallon, and emitted 568 tons of NO_X, 162 tons of VOC, and 15 tons of PM.

- **1,113 school buses** traveled 18.7 million miles, used 2.8 million gallons of diesel-fuel, achieved a fuel efficiency of 6.7 miles per gallon, and emitted 272 tons of NO_X, 77 tons of VOC, and 9 tons of PM.

- **322[5] transit buses** traveled 13.4 million miles, used 3.5 million gallons of fuel, achieved an efficiency of 3.8 miles per gallon, and emitted 296 tons of NO_X, 85 tons of VOC, and 6 tons of PM.

    - 217 full-size diesel buses traveled 9.7 million miles, used 2.5 million gallons of fuel, operated at an overall fuel efficiency of 3.9 miles per gallon, and emitted 234 tons of NO_X, 65 tons of VOC, and 6 tons of PM.

    - 24 full-size compressed natural gas (CNG) buses traveled 1.2 million miles, used 460,000 gallons[6] of fuel, operated at an overall fuel efficiency of 2.6 miles per gallon, and emitted 11.2 tons of NO_X, 2.5 tons of VOC, and .06 tons of PM.

    - 81 mini-buses traveled 2.5 million miles, used approximately 540,000 gallons of fuel (gasoline and diesel), achieved an efficiency of 4.6 miles per gallon, and emitted 51 tons of NO_X, 16.5 tons of VOC, and .5 tons of PM.

EXHIBIT 17: BUS FLEET COMPOSITION AND POLLUTANTS – FY 02

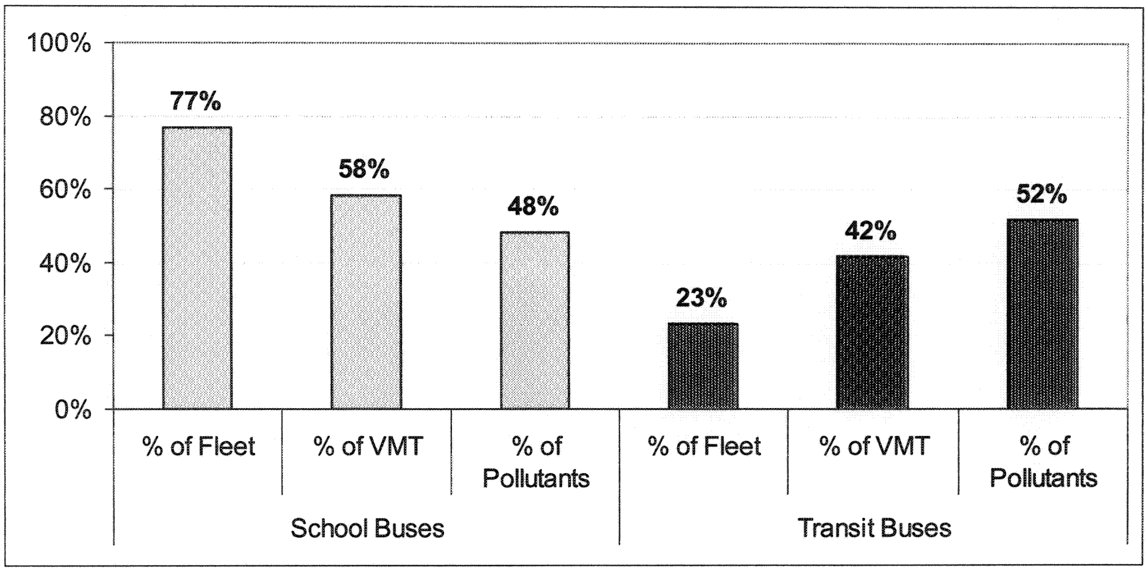
Fleet	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel (millions)	Miles per Gallon	# of Pollutants (Tons)		
					NOx	VOC	PM
MCPS School Buses	1,113	18.7	2.8	6.7	272	77	9
DPWT Transit Buses	322	13.4	3.5	3.8	296	85	6
Total	**1,435**	**31.4**	**6.3**	**5.1**	**568**	**162**	**15**

[5] DPWT owns 337 transit buses: 217 full-size diesels; 24 full-size CNGs; and 96 mini-buses. DPWT were unable to provide vehicle data for 15 mini-buses. OLO's emission analysis of the County's transit fleet is based on 322 vehicles.

[6] CNG gallons of fuel reported in diesel gallon equivalents (DGE).

Exhibit 18 shows the relationships between mileage and pollution for the combined bus fleet. In FY 02, transit buses traveled 42 percent of the total bus miles, but emitted 52 percent of all pollution.

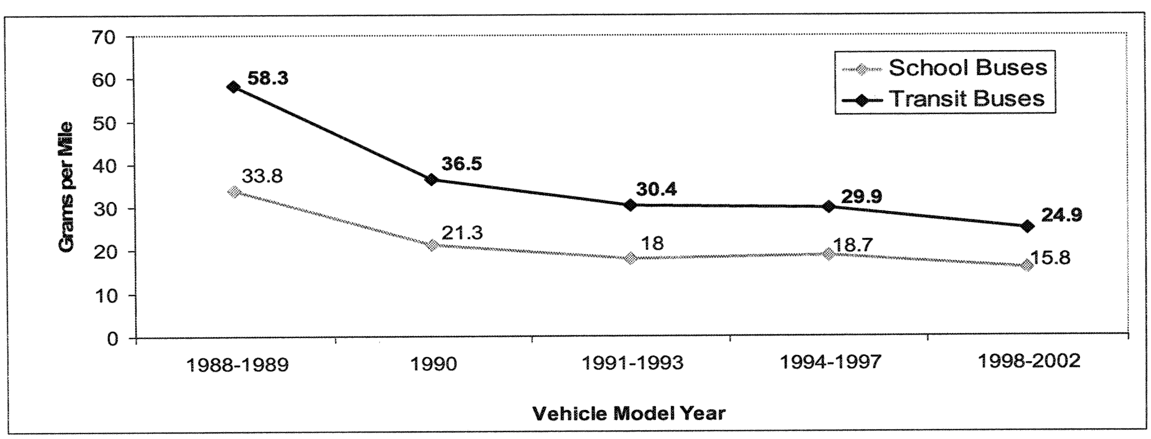
EXHIBIT 18: SUMMARY OF TRANSIT AND SCHOOL BUS FLEET EMISSIONS – FY 02



Source: OLO, May 2003

Transit buses have higher rates of pollution than school buses for many reasons. Compared to school buses, transit buses are heavier, have larger engines which operate at higher revolutions per minute, travel in more stop and go traffic, operate on longer routes for more hours and have air conditioning. OLO compared the pollution rates of transit buses and school buses by model year and found that the transit bus pollution rates were consistently 1.5 times more than the school bus pollution rates.

EXHIBIT 19: COMPARISON OF DIESEL TRANSIT AND SCHOOL BUS EMISSION RATES



Source: OLO, May 2003

Buses purchased prior to 1991 are the highest polluters in the transit and school bus fleets in FY 02. In FY 02 there were 17 pre-1991 transit buses and 120 pre-1991 school buses, which were used to transport children.[7] On average, the older buses in each fleet traveled fewer miles than the newer buses. This helped to reduce the pollution of the bus fleet. In FY 02,

- The average mileage for the 17 older transit buses traveled was 18,600 miles, compared to 43,000 miles for the newer buses.

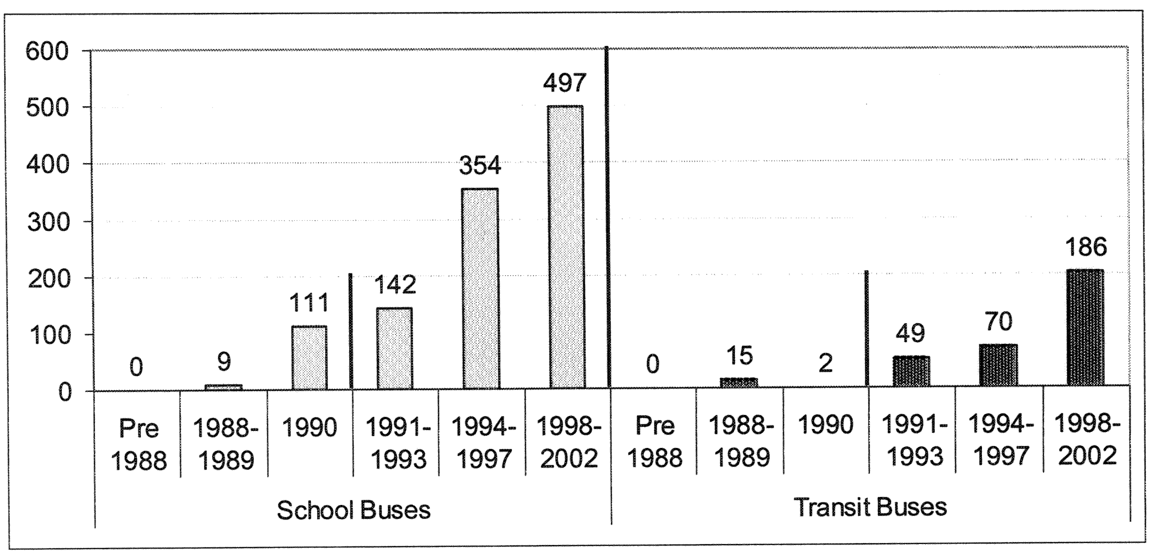
- The average mileage for the 120 older school buses was 12,300 miles, compared to 17,300 miles for the newer school buses.

EXHIBIT 20: AVERAGE MILES TRAVELED IN FY 02 - PRE AND POST 1991 BUSES

Type of Vehicle	Vehicle Miles Traveled	Number of buses	Average Miles Traveled per Vehicle
Transit Buses			
Older (pre-1991) Buses	315,000	17	18,600
Newer Buses	13,036,000	305	43,000
School Buses			
Older (pre-1991) Buses	1,473,000	120	12,300
Newer Buses	17,227,000	993	17,300

Source: OLO, May 2003

EXHIBIT 21: DISTRIBUTION OF BUSES BY AGE IN FY 02[8]



Source: OLO, May 2003

[7] MCPS owns eight pre-1991 buses which the Supply, Maintenance and Food Services Departments have converted for use as heavy trucks. The emissions for these eight vehicles are calculated as heavy truck rates.
[8] MCPS buses include only those used to transport children.

Montgomery County Government (MCG) On-Road Car and Truck Fleet (Excludes Transit Buses)

In FY 02, MCG maintained a fleet of 2,484 cars and trucks that traveled 27.9 million miles, used 2.2 million gallons of fuel and operated at an overall efficiency of 12.7 miles per gallon.

- **1,506 passenger cars** traveled 20.1 million miles.
- **389 light trucks** (including 205 SUVs) traveled 4.6 million miles.
- **589 heavy trucks** traveled 3.2 million miles.

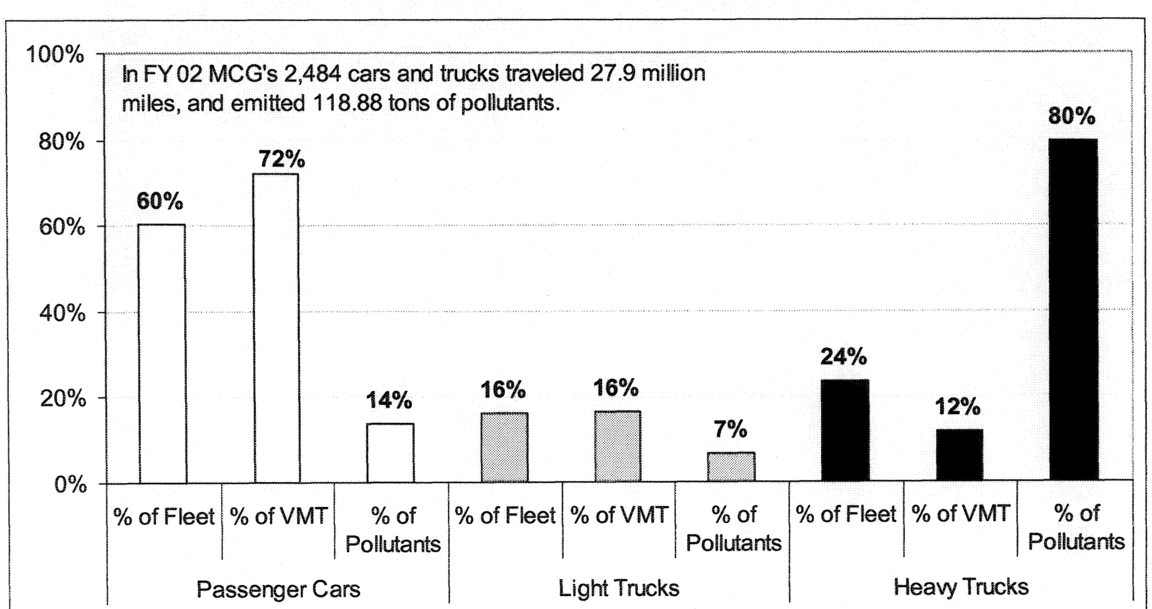
Exhibit 22: MCG Car and Truck Composition and Pollutants - FY 02

Vehicle Class	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel (millions)	Miles per Gallon	Total Emissions (Tons)
Passenger Cars	1,506	20.1	N/A	N/A	16.47
Light Trucks	389	4.6	N/A	N/A	7.82
Heavy Trucks	589	3.2	N/A	N/A	94.59
Totals	**2,484**	**27.9**	**2.2**	**12.7**	**118.88**

Source: MCG and OLO May, 2003

The MCG car and truck fleet emitted 88 tons of NO_X, 26 tons of VOC, and 5 tons of PM. Heavy trucks represented 24 percent of the fleet, 12 percent of the mileage, and emitted 80 percent of the pollutants.

Exhibit 23: Summary of MCG Cars and Trucks - FY 02



Source: OLO, May 2003

In FY 02, MCPS maintained a fleet of 564 cars and trucks that traveled 3.4 million miles, used 389,000 gallons of fuel and operated at an overall fuel efficiency of 8.7 miles per gallon.

- **100 passenger cars** traveled 0.8 million miles.
- **243 light trucks** (including 13 SUVs) traveled 1.2 million miles.
- **221 heavy trucks** traveled 1.4 million miles.

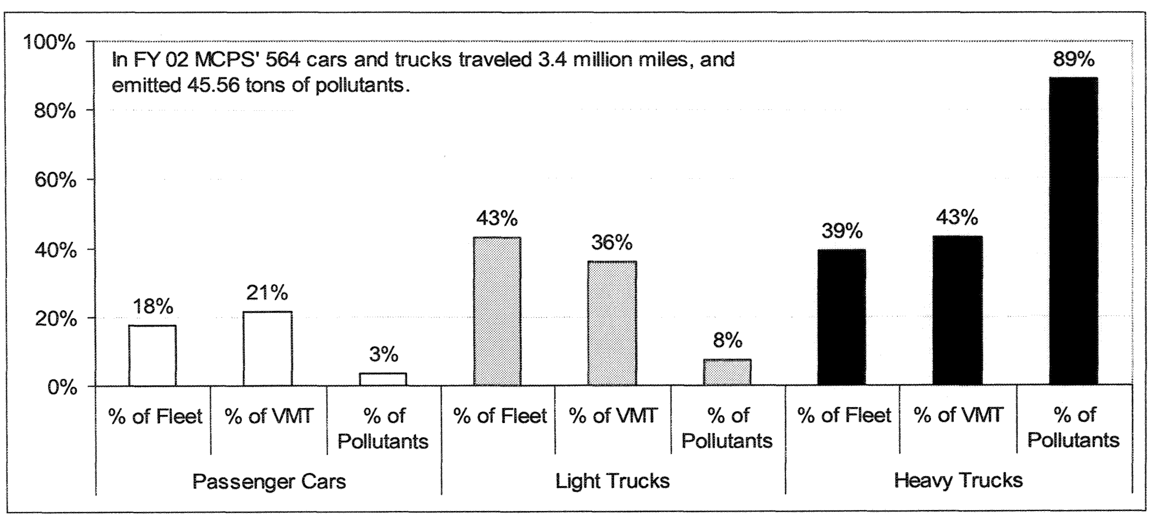
EXHIBIT 24: MCPS CAR AND TRUCK COMPOSITION AND POLLUTANTS - FY 02

Vehicle Class	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel	Miles per Gallon	Total Emissions (Tons)
Passenger Cars	100	0.8	N/A	N/A	1.54
Light Trucks	243	1.2	N/A	N/A	3.45
Heavy Trucks	221	1.4	N/A	N/A	40.57
Totals	**564**	**3.4**[9]	**389,122**	**8.7**	**45.56**

Source: MCPS and OLO May, 2003

The MCPS car and truck fleet emitted 36.5 tons of NO_X, 7.5 tons of VOC, and 1.5 tons of PM. Heavy trucks represented 39 percent of the fleet, 43 percent of the mileage, and emitted 89 percent of the pollutants.[9]

EXHIBIT 25: SUMMARY OF MCPS CARS AND TRUCKS - FY 02



Source: OLO, May 2003

[9]MCPS was not able to provide annual mileage by individual vehicle so OLO created a data set of FY 02 vehicle mileage estimates based on lifetime mileage and model year data for each vehicle. OLO used actual FY 02 mileage data recorded by department to determine the total actual FY 02 mileage. OLO added the FY 02 vehicle mileage estimates and compared this sum to the total actual FY 02 mileage by department. The total estimated mileage (by vehicle) was 15 percent higher than the total actual mileage (by department), so OLO reduced the estimated emissions by 15 percent.

In FY 02, WSSC maintained a fleet of 871 cars and trucks that traveled 8.0 million miles, used 548,000 gallons of fuel and operated at an overall fuel efficiency of 14.6 miles per gallon.

- **122 passenger cars** traveled 0.8 million miles, used 26,000 gallons of unleaded gasoline, and achieved an efficiency of 31.0 miles per gallon.
- **568 light trucks** (including 175 SUVs) traveled 6.1 million miles, used 326,000 gallons of fuel and operated at an efficiency of 18.7 miles per gallon.
- **181 heavy trucks** traveled 1.1 million miles, used 196,000 gallons of diesel and achieved an efficiency of 5.6 miles per gallon.

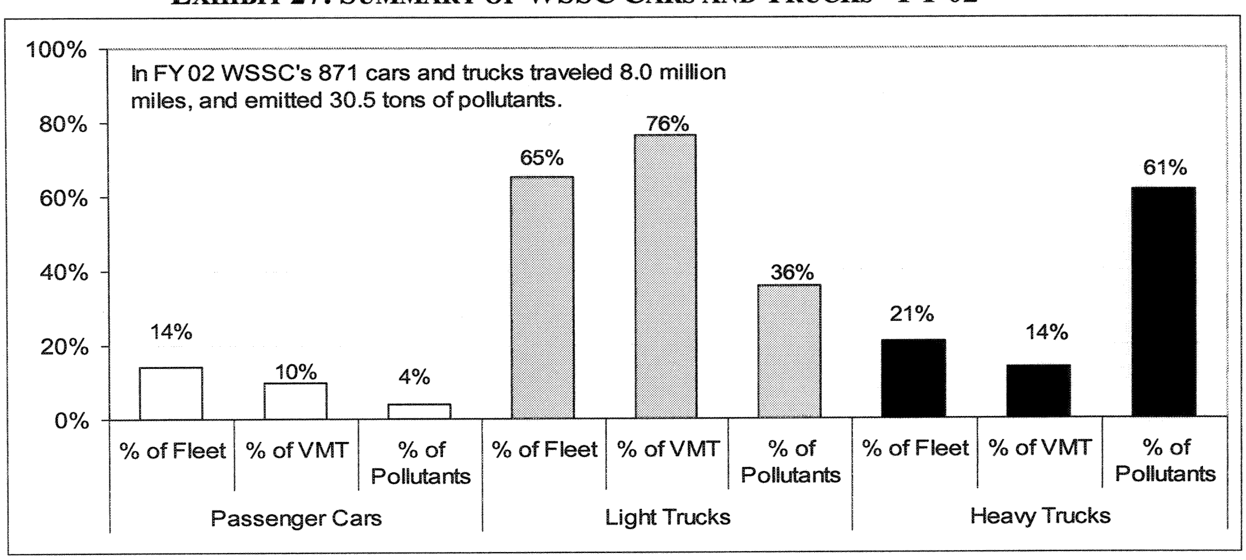
EXHIBIT 26: WSSC CAR AND TRUCK COMPOSITION AND POLLUTANTS - FY 02

Vehicle Class	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel	Miles per Gallon	Total Emissions (Tons)
Passenger Cars	122	0.8	26,000	31.0	0.90
Light Trucks	568	6.1	326,000	18.7	10.90
Heavy Trucks	181	1.1	196,000	5.6	18.70
Totals	**871**	**8.0**	**548,000**	**14.6**	**30.50**

Source: WSSC and OLO, May 2003

The WSSC car and truck fleet emitted 21 tons of NO_X, 8 tons of VOC, and 1.5 tons of PM. Heavy trucks represented 21 percent of the fleet, 14 percent of the mileage and emitted 61 percent of the pollutants.

EXHIBIT 27: SUMMARY OF WSSC CARS AND TRUCKS - FY 02



Source: OLO, May 2003

MARYLAND-NATIONAL CAPITAL PARK AND PLANNING COMMISSION (M-NCPPC) ON-ROAD CAR AND TRUCK FLEET

In FY 02, M-NCPPC maintained a fleet of 528 cars and trucks that traveled 4.6 million miles, used 371,083 gallons of fuel, and operated at an overall fuel efficiency of 13 miles per gallon.

- **154 passenger cars** traveled 1.8 million miles, used an estimated 100,634 gallons of fuel, and achieved fuel efficiency of 16.9 miles per gallon.
- **198 light trucks** (including 46 SUVs) traveled 1.6 million miles, used an estimated 105,634 gallons of fuel, and achieved fuel efficiency of 14.2 miles per gallon.
- **176 heavy trucks** traveled 1.2 million miles, used an estimated 151,899 gallons of fuel, and achieved fuel efficiency of 7.9 miles per gallon.

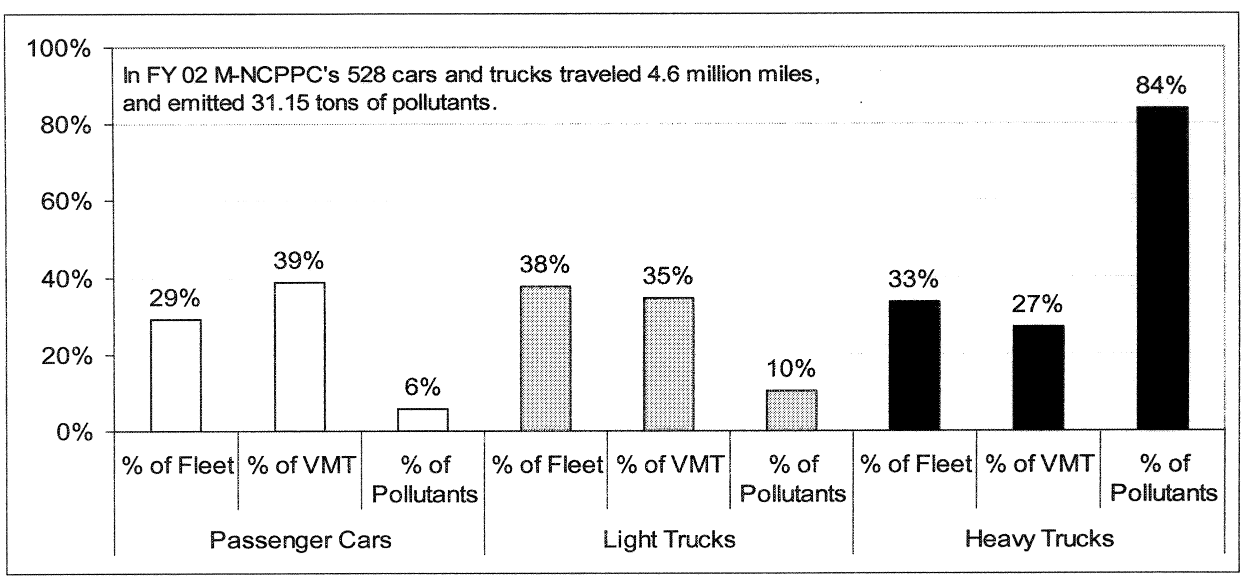
EXHIBIT 28: M-NCPPC CAR AND TRUCK COMPOSITION AND POLLUTANTS - FY 02*

Vehicle Class	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel	Miles per Gallon	Total Emissions (Tons)
Passenger Cars	154	1.8	106,508	16.9	1.77
Light Trucks	198	1.6	112,676	14.2	3.23
Heavy Trucks	176	1.2	151,899	7.9	26.25
Totals	**528**	**4.6**	**371,083**	**12.4**	**31.25**

Source: M-NCPPC and OLO May, 2003
*"Gallons of Fuel" and "Mile per Gallon" columns estimates developed by M-NCPPC and OLO staff.

The M-NCPPC car and truck fleet emitted 24 tons of NO_X, 6.5 tons of VOC, and one ton of PM. Heavy trucks represented 33 percent of the fleet, 27 percent of the mileage, and emitted 84 percent of the pollutants.

EXHIBIT 29: SUMMARY OF M-NCPPC CARS AND TRUCKS - FY 02



Source: OLO, May 2003

MONTGOMERY COLLEGE (MC) ON-ROAD CAR AND TRUCK FLEET

In FY 02, MC maintained a fleet of 44 cars and trucks that traveled 185,000 miles, and emitted 1.70 tons of pollutants.

- **One passenger car** traveled 18,000 miles.
- **21 light trucks** (including one SUV) traveled 89,000 miles.
- **22 heavy trucks** traveled 78,000 miles.

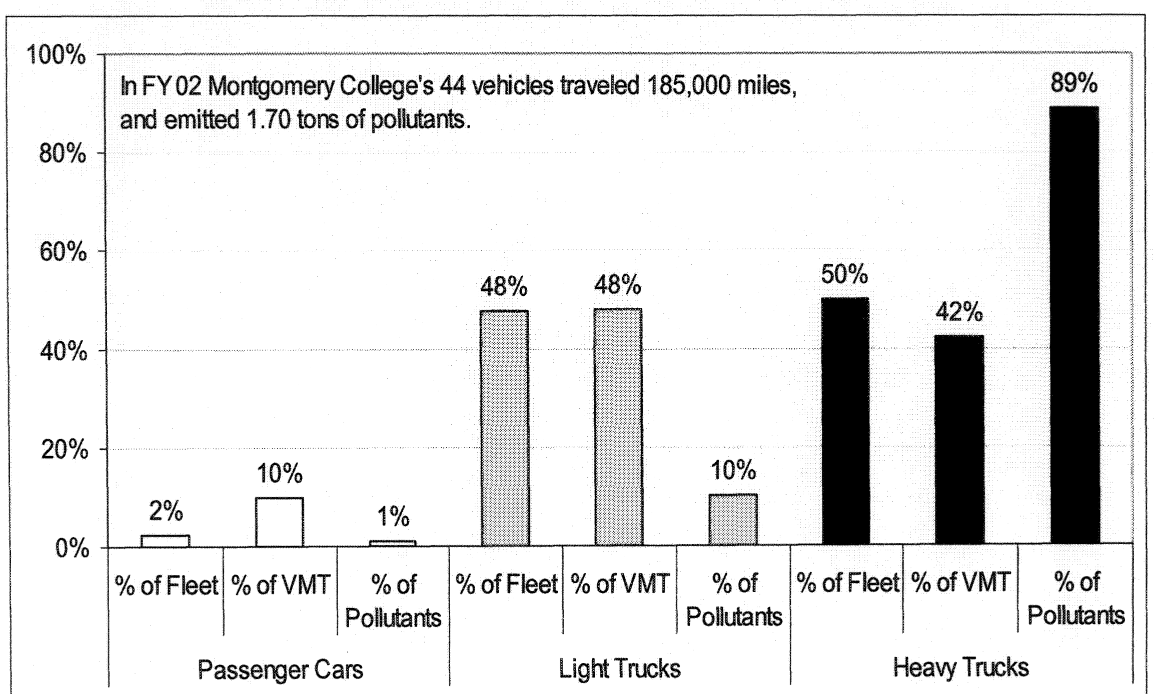
EXHIBIT 30: MC CAR AND TRUCK COMPOSITION AND POLLUTANTS - FY 02

Vehicle Class	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel	Miles per Gallon	Total Emissions (Tons)
Passenger Cars	1	18,000	N/A	N/A	0.02
Light Trucks	21	89,000	N/A	N/A	0.18
Heavy Trucks	22	78,000	N/A	N/A	1.50
Totals	**44**	**185,000**	**N/A**	**N/A**	**1.70**

Source: MCC and OLO May, 2003

The MC car and truck fleet emitted 1.2 tons of NO_X, 0.4 tons of VOC, and 0.1 tons of PM. Heavy trucks represented 50 percent of the fleet, 42 percent of the mileage, and emitted 89 percent of the pollutants.

EXHIBIT 31: SUMMARY OF MC CARS AND TRUCKS - FY 02



Source: OLO, May 2003

V. Vehicle Emission Control Strategies and Agency Practices

In recent years, an array of management practices and technology solutions has emerged to reduce fleet vehicle emissions. This chapter describes the following promising strategies and reports the extent to which the five County and bi-County agencies currently use them:[1]

- Perform routine preventive maintenance;
- Encourage driving habits that conserve energy, e.g., limit idling;
- Use fuel efficient vehicles;
- Manage size of vehicle fleet;
- Replace older vehicles with more fuel efficient or cleaner burning vehicles;
- Consider use of alternatively fueled vehicles;
- Use diesel fuel additives or ultra-low sulfur diesel fuel; and
- Retrofit existing diesel engines.

As will be described below, some of the strategies apply to all types of vehicles while others apply only to heavy-duty diesel trucks and buses.

A. Perform routine preventive maintenance

Preventive inspection and maintenance programs ensure vehicles operate at their maximum efficiency. There are different levels of inspection and maintenance programs; for example:

- A vehicle operator can inspect a vehicle weekly to check the tire pressure, the oil and coolant levels and look for fluid leaks.

- A fleet manager can establish a routine maintenance program for all vehicles, which includes a regularly scheduled visual inspection, lubrication, and adjustment, cleaning, testing (and replacement) of certain vehicle components.

Through its authority in the Clean Air Act, the federal EPA requires regular state vehicle inspection and repair programs to detect whether a passenger or light duty vehicle is in violation of emission standards. In nonattainment areas, states must test the emissions systems of a vehicle annually or biannually to make sure it meets adopted standards. If a vehicle fails the test, the owner must repair the vehicle and have it retested.[2]

Owners of large fleets (e.g., public sector agencies) may establish their own approved inspection and maintenance program or utilize the state operated facility. See the following pages for a brief description of the inspection and maintenance programs in the five county and bi-county agencies.

[1] The list of strategies is not an all inclusive list. For example, this chapter does not address the potential emission benefits of shared ride services; traffic flow improvements, and pedestrian and bicycle programs.
[2] These tests are for light duty vehicles only.

County and bi-County agency practices. All agencies participate in the state's vehicle emissions and inspection program for passenger vehicles and some agencies provide additional preventive maintenance programs.

- MCPS and the College conduct vehicle emission tests at the State inspection stations.

- WSSC, and M-NCPPC operate in-house vehicle emission inspection facilities with agency employees who are certified by the State. The emission tests are conducted on-site and the State routinely inspects the records and equipment.

- MCG operates an on-site vehicle emissions inspection facility that is staffed by contract employees. MCG also participates in the State's program for diesel emission testing for heavy trucks.

Four agencies, MCG, WSSC, M-NCPPC, and the College, conduct routine preventive maintenance for their light and heavy duty fleets. The fleet managers report that preventive maintenance helps ensure that their fleets operate safely. Agency fleet managers recognize that properly maintained vehicles have lower emission levels and that routine maintenance offers an opportunity for mechanics to identify and fix exhaust problems sooner; however this is generally perceived as a secondary benefit.

- MCG performs maintenance on public safety vehicles every 2,000 miles, on administrative vehicles every 3,000 miles, and on heavy duty vehicles, including buses, every 6,000 miles. This schedule means that buses receive maintenance as frequently as once a month.

- WSSC conducts maintenance on its light and heavy duty vehicles on a four month schedule.

- M-NCPPC performs maintenance on light and heavy duty vehicles every 5,000 miles or six months.

- The College provides preventive maintenance every 3,000 miles or every six months.

MCPS reports that fiscal constraints have affected the level of maintenance it can provide for its light duty and heavy duty fleets.[3] MCPS provides oil changes for its light duty fleet every 3,000 to 5,000 miles and performs repairs on an as-needed basis. MCPS used to provide preventive maintenance for its heavy duty fleets; however, as enrollment has grown over time, resources have been diverted to the classroom and the remaining fleet resources have been dedicated to maintaining the school buses. As a result, maintenance is performed on MCPS' heavy duty fleet vehicles on an as-needed basis only.

---

[3] Three MCPS divisions share preventive maintenance responsibilities: Transportation maintains school buses, and pool and transportation cars; Facilities Management maintains maintenance vehicles; and Materials Management maintains food service and other supply vehicles.

State law requires MCPS to provide three safety inspections and one preventive maintenance inspection for each bus annually. The safety inspections consist of adjusting brakes, checking for leakage and inflating tires. State law also requires an additional inspection for school buses which are kept beyond the replacement cycles set in state law. These inspections must be performed by an independent third party contractor. (See page 42 for further discussion of this law.)

B. Encourage driving habits that conserve energy

The driver of a vehicle can significantly affect fuel efficiency. Limiting idle time, avoiding unnecessary driving, adhering to speed limits, and increasing speed gradually, can help reduce emissions.

Limiting idling not only reduces emissions but also saves money and maintenance. A typical heavy duty truck burns approximately one gallon of fuel for each hour it idles. A study by Argonne National Laboratory for the U.S. Department of Energy found that a large semi-truck could emit 144 grams/hour of NO_X and 8224 grams/hour of carbon dioxide.

Technology solutions for heavy duty vehicles exist to reduce idling time. Auxiliary power units provide heating and air conditioning and power for the cab. Block heaters can be used to keep engines warm in cold climates. An EPA study reported emission reductions of 90 to 100 percent due to idling reduction devices.

Many governments and businesses require employees to take driver safety courses/tests before driving agency vehicles. Some places have expanded these programs to emphasize fuel-efficient driving. For example, Edmonton City, Alberta implemented a training program that provides drivers hands-on training about fuel-efficient driving. Test results show that the program yielded 20 percent savings in fuel costs. Drivers receive regular monthly feedback through reports which track fuel consumption by month, quarter and year.

County and bi-County agency practices. The five agencies use a combination of special procedures for Ozone Action (Code Red) days and idling policies to encourage vehicle operators to manage emissions.

Many jurisdictions classified as nonattainment areas for ozone implement special procedures to manage emissions during the ozone season from May to September. In the Washington metropolitan area, the Washington Area Council of Governments receives ozone forecasts that it communicates to local governments and other participants as part of its Ozone Action Day program. Ozone action day policies vary across the agencies.

- MCG has written protocols to curtail activities and provide free transit service when an ozone day is forecast. On a Code Red day, MCG provides free trips on Ride-On, and curtails operation of the Resource Recovery Facility, center line painting, lawn mowing, median strip herbicide application and asphalt paving. The County also posts a sign at the fueling stations asking employees to defer refueling of County vehicles until after 7:00 p.m. The refueling schedule for County transit buses does not change on Code Red days. Diesel transit buses are regularly refueled in the evenings already and the CNG buses have to be refueled at midday. (See Appendix B ©28 for the Summer 2003 Ozone Action Day Communication Protocol, prepared by the Department of Environmental Protection.)

- WSSC has standard procedures in place for Code Red days under its written Clean Air Policy. This policy restricts fleet refueling to early morning hours, prohibits the use of gasoline powered mowers, trimmers and lawn care equipment and also prohibits outdoor painting or cleaning of facilities. (See Appendix C, ©36, for WSSC Standard Procedure ENG 02-01.)

- MCPS' Transportation Division fuels its buses every day or every other day at a time chosen by each individual driver. MCPS' Facilities Management and Materials Management Divisions:[4]

    - Restrict refueling to early morning hours (whenever possible);
    - Restrict routine grass cutting and use of gasoline powered lawn maintenance equipment;
    - Require vehicle drivers to turn off engines (whenever possible);
    - Suspend outdoor painting or exterior use of materials containing volatile compounds; and
    - Re-assign employees that usually work on outdoor activities to indoor duties.

- M-NCPPC defers fueling on Code Red days. The agency, however, does not typically defer mowing because of tight schedule constraints.

- The College defers outside maintenance jobs and brings workers inside on Code Red days.

MCG, WSSC, MCPS and M-NCPPC also have policies on vehicle idling; the College does not have an idling policy.

- MCG Transit Services' idling policy requires operators to turn off buses at the end of the line and to not start buses earlier than three minutes before departure. In the past, MCG experimented with programming its transit buses to shut off automatically; however when the bus operators raised concerns, the Department discontinued this practice. (See Appendix M, ©122 for Transit Services' Idling Policy.)

[4] These divisions maintain food service, maintenance, and other supply vehicles.

- MCG Highway Maintenance reports most of its vehicle idling takes place in the winter months in order to keep the equipment running and provide a place for the operators to sleep. (There is insufficient bunk space at headquarters.) Highway Maintenance does not have a written idling policy but uses a common sense approach of limiting idling and other activities on Code Red days during the summer months.

- WSSC addresses idling in writing through its Clean Air Policy, which requires vehicle and equipment operators to turn off motors whenever possible. (See Appendix C ©36 for the WSSC Clean Air Policy.)

- MCPS asks drivers to limit idling to five minutes and reinforces this policy informally through newsletters, training programs and supervisors at the schools. On cold winter mornings, however, MCPS warms up the bus fleet and idles buses for up to two hours. MCPS staff explain that this practice developed because MCPS has an undersized reserve bus fleet and, as a result, could not replace buses that would not restart.

- M-NCPPC has a policy that idling of equipment should be limited to 30 seconds; however there is no routine enforcement of this policy.

C. Use fuel efficient vehicles

Engine efficiency translates into lower fuel consumption and lower emission levels. A high efficiency vehicle can get up to 25 percent better fuel mileage than a low efficiency model within the same vehicle class. Appendix D, ©42, shows the fuel efficiency standards and vehicle emission standards for a range of vehicle types.

Nationally, EPA reports that consumers are moving toward larger, heavier, less fuel efficient vehicles. In some cases, consumer trends have influenced the mix of vehicles in local government fleets.

In most cases, a small vehicle is more fuel efficient than a large vehicle.[5] Generally, fleet managers can improve the fuel efficiency of their fleets by selecting the smallest vehicles necessary to get the job done. Some jurisdictions have modified their procurement practices to require the "most fuel efficient model available that will fulfill the intended function." For example:

- Denver, Colorado puts specific mile per gallon (mpg) standards in its bid specifications. In 1994, these standards required 27.5 mpg for light duty cars and 19 mpg for light duty trucks and vans. As a result, more than 90 percent of Denver's vehicle fleet consists of compacts or sub-compacts.

---

[5] Industry experts advise that small vehicle don't necessarily emit less pollution. Some large vehicles are equipped with technologically superior pollution control devices.

- Louisville, Kentucky specifies the minimum power needed for the specific use of a vehicle. This approach addresses performance and safety requirements while identifying opportunities to reduce vehicle size.

County and bi-County agency practices. Two agencies, MCG and WSSC, have adopted procedures that require a review of whether a requested vehicle is the appropriate size for the job. In addition, MCG manages the size of Ride On buses on their routes.

- In the County Government, the Chief of Fleet Management Services and the Office of Management and Budget review and sign off on all vehicle requests. The review includes an assessment of whether the requested vehicle is the appropriate size for the job.

- In WSSC, the Team Leader for Mission Support reviews each vehicle request

- Ride On sizes their transit buses to the ridership of the route. Most routes start out with smaller transit buses until the ridership warrants going to a larger bus. In this manner, Ride On is managing emissions and using the most efficient bus to provide service.

MCPS, M-NCPPC and the College do not have any formal procedures in place to review vehicle size. MCPS states that the agency rarely purchases administrative vehicles. The College and M-NCPPC fleet managers report that they regularly consult with managers about the maintenance implications of purchasing a specific vehicle, but do not make final purchasing decisions.

In some cases, agency staff choose smaller vehicles for other reasons. For example, in FY 04 the College will replace six heavy-duty passenger vans with eight light-duty vans because of nationally recognized safety issues related to 16-passenger vehicles. The College expects delivery of four new vans by June 30 and the other four vehicles next year (depending on funding). The College plans to retain four of the six old heavy-duty vans for on-campus use only. Fleet staff estimate that these old vans will travel fewer than 500 miles per year.

D. Manage size of vehicle fleet

Routinely assessing user needs and minimizing overall fleet size helps to maximize efficiency and limit easy access to vehicles. Keeping fewer vehicles can reduce vehicle use, save fuel, and reduce capital and maintenance costs. For example:

- A vehicle utilization study conducted in Long Beach California led to the removal of 100 vehicles from the fleet. A study in Oakland led to the elimination of 90 vehicles and heavy equipment. In San Antonio, employee take home vehicles were eliminated.

- In some cases, jurisdictions replace vehicles with other forms of transportation. Several cities, including New York City, Dayton, Seattle and Tucson, reduced the number of police vehicles by establishing a 'Cops on Bikes' program.

- Since implementing its chargeback system, Edmonton City (Alberta) fleet managers report a drop in total fleet size and better utilization of the remaining vehicles.

County and bi-County agency practices. WSSC reduced the size of its vehicle fleet as part of the agency's recent organizational downsizing. In 1998, WSSC operated a fleet of 943 vehicles to support 2,100 employees; in 2003, WSSC maintains a fleet of 804 vehicles to support 1,457 employees. WSSC reports that the result of training workers to perform many different tasks has been the assignment of smaller crews and fewer vehicles to a job. Additionally, WSSC is moving away from a concept of maintaining an inventory to support a worst case scenario. WSSC anticipates it will reduce staff and vehicles by an additional ten percent in the future.

In the other four agencies (MCG, M-NCPPC, MCPS, and the College), the user departments determines the sizes of the light duty and heavy duty fleets. The respective agency fleet managers do not routinely conduct comprehensive assessments of user needs; however they may monitor the use of the fleet.

The size of the MCPS school bus fleet is determined by a range of factors including enrollment, the Board of Education's transportation policies, and state/federal requirements. In recent years, the fleet has expanded primarily to support enrollment growth; since 2001, MCPS has purchased 180 buses to meet increased service demands.

The size of the MCG Ride On transit fleet is demand driven. The County uses an industry standard of ten riders per bus hour as a minimum threshold to support a new transit route. When demand increases during peak hour service, the County will purchase additional buses to maintain the service level and standards of service reliability.

E. Replace older vehicles with more fuel efficient or cleaner burning vehicles

Following regular replacement cycles helps fleet managers replace older vehicles with more fuel efficient or cleaner burning vehicles over time. The cited advantages of regular replacement cycles include:

- Higher salvage values;
- Better availability of parts;
- Standardized equipment;
- Improved safety records; and
- Lower training costs.

Older transit and school buses emit pollutants at significantly higher rates than newer buses. The Union of Concerned Scientists (UCS) reports that buses built before 1990 and 1991 are allowed to emit at least six times more particulate matter and almost three times more NO_X than today's models.[6]

An effective strategy for significantly reducing vehicle emissions is to replace older buses with new, clean vehicle technology. Clean technology options include advanced clean diesel buses; or alternatively-fueled buses that run on ethanol, methanol, propane or natural gas. The most promising technologies are clean diesel, compressed natural gas buses, and hybrid electric buses. These technologies are in different stages of development. (The following section more specifically addresses the use of alternatively-fueled vehicle.)

County and bi-County agency practices. Exhibit 32 shows the light and heavy duty vehicle replacement policies for MCG, WSSC and M-NCPPC. MCG's use of its replacement cycles to incorporate CNG-fueled vehicles into its fleet is explained further in the following section on the use of alternatively-fueled vehicles.

EXHIBIT 32: COUNTY AND BI-COUNTY AGENCIES REPLACEMENT POLICIES

	MCG	WSSC	M-NCPPC
Light Duty	6 years for Police cruisers 8 years for sedans 9 years for SUVs	7 years or 85,000 miles	10 years or 100,000 miles
Heavy Duty	8-10 years for passenger vans 12 years for heavy trucks	10 years or 100,000 miles	15 years or 150,000 miles for trucks over 1 ton

Source: OLO, May 2003

MCPS and MCG bus replacement cycles. MCPS' adopted replacement cycles for its buses reflect the replacement cycles established in state law (Maryland COMAR 13A02.07). The law requires MCPS to replace conventional buses every 12 years and other buses every 15 years.

State law also provides a procedure to request a waiver from these provisions. Since 2001, the state has granted MCPS a waiver to defer the replacement of 78 buses. MCPS staff recognize that these buses emit more pollutants than the newer buses in the fleet.[7] MCPS staff also expressed concerns that these buses do not have the upgraded safety equipment, such as brakes, roof hatches, child find buttons and strobe lights, which has been specified for more recent purchases. These older buses also have higher maintenance costs because state law requires an additional inspection.

[6] The Union of Concerned Scientists conducted a graded school bus fleets in the 50 states based on their emissions of particulates, smog forming pollution and green house gases. No states received an 'A'; six states (including Maryland) and the District of Columbia received a 'B'; 23 states received an average 'C', and the remaining 21 states fared poorly. UCS report that three states, Maryland, Delaware and the District of Columbia, have effective policies to ensure that older buses are removed from the road. Delaware and Maryland require that school buses be retired after 12 or 14 years of operation.
[7] For example, a bus built in 1989 bus emits pollutants at twice the rate of a bus built in 2002.

MCG plans to replace full size transit buses every 12 years and smaller size mini-buses every six or seven years. This replacement schedule creates opportunities to replace older buses with cleaner buses over time.

F. Consider Use of Alternatively Fueled Vehicles (AFV) on New Hybrid Technologies

Using vehicles that operate with fuels that burn more cleanly than gasoline and regular diesel can reduce vehicle emissions. Common alternative fuels used by public sector fleets include ethanol, and compressed natural gas (CNG). These fuel alternatives currently provide lower emissions than diesel and gasoline. (See Appendix E ©46 for a chart that compares the environmental and vehicle performance of these alternative technologies.) Hybrid electric propulsion is also a promising emerging strategy.

Currently, the most reliable alternative fuel options for transit buses and school buses are compressed natural gas (CNG) and ultra low sulfur diesel fuel. Buses fueled with CNG reduce the emissions of NO_X, PM, and NMHC. Buses fueled with ultra low sulfur diesel reduce particulate matter emissions. EPA regulations will require the use of ultra low sulfur diesel fuel beginning June 1, 2006. See Appendix J, ©95, for a more information about the capital and operating costs of these technologies.

- Diesel buses are an established technology. In 2007, new EPA emission standards are scheduled to take effect that would reduce the emissions of nitrogen oxide and volatile organic compounds to levels below those of a model year (MY) 2004 CNG bus. In 2010, standards are scheduled to take effect which would reduce nitrogen oxide and particulate matter even further.

- Compressed natural gas buses are commercially available today. Their emission standards are expected to improve to keep pace with clean diesel buses.

- Hybrid electric propulsion is an emerging technology for the next generation of transit buses. Experts expect energy consumption and emissions to be 30 to 40 percent lower than the current baseline.

Most of the alternative fuels used today require specialized vehicles as well as conversion of the fueling infrastructure. The expense of converting vehicles and building additional fueling stations is often cited as a major obstacle to using alternatively fueled vehicles. Examples of jurisdiction using alternatively-fueled vehicles are listed below.

- In 1991, King County converted 74 police vehicles to bi-fuel gasoline/CNG vehicles. Since conversion, the bi-fuel vehicles achieve a CNG usage of about 51 percent. County officials report that the officers needed training to adjust to the heavier bi-fuel vehicles.

- More than three-quarters of the marked patrol cars operated by the Mesa Police Department in Maricopa County Arizona are alternatively fueled. Of the 315 marked cars, 178 are CNG only and 65 are bi-fueled Ford Crown Victorias.
- The City of Boulder's 38 alternative fuel vehicles includes 12 bi-fuel gasoline/propane vehicles, nine hybrid gasoline electric vehicles, seven dedicated propane vehicles, and eight flex fuel gasoline/ethanol vehicles.

- One-quarter of the State of Minnesota's vehicle fleet based in St. Paul is capable of fueling with ethanol; however ethanol represents only 10 percent of the fuel consumption.

- Illinois operates a fleet fueled by ethanol. El Paso Mass Transit operates with Liquid Natural Gas (LNG) fuel.

County and bi-County agency practices. In the early 1990's, all five agencies tested a handful of vehicles that were converted to use CNG fuel. Consistent feedback from agency staff was that these converted vehicles were problematic. Agencies reported that the vehicles had acceleration and mechanical problems, a limited fuel range, and were difficult to maintain. For example, the College reported that maintenance for its bi-fueled gasoline/CNG vehicles was only available in Lorton, Virginia or Martinsburg, West Virginia.

In addition, M-NCPPC and College staff observed that the limited number of fueling sites for CNG vehicles posed problems; both agencies now operate the CNG vehicles on unleaded gasoline. MCPS currently operates its three CNG buses for training purposes only.

WSSC has also discontinued use of its CNG vehicles since its pumps were removed by Washington Gas. In addition to CNG, WSSC used to operate fifteen propane vehicles fueled from three sites. When EPA required an environmental impact study to maintain the propane fuel sites, WSSC chose to eliminate its propane vehicles. Today, WSSC operates propane forklifts fueled with propane tanks.

Comparatively, MCG operates the largest fleet of alternatively fueled vehicles. Currently, MCG has 74 (passenger and light) alternatively fueled cars and trucks, including:

- 12 CNG sedans;
- 60 cars and light trucks which operate on ethanol or unleaded gasoline, and
- Two hybrid electric passenger cars.

These vehicles represent 2.9 percent of the County's non-bus fleet and 3.2 percent of its annual mileage. MCG reports that user compliance is a challenge in relying on alternatively fueled vehicles to manage emissions. As an example, users are not regularly fueling the flexibly fueled vehicles with ethanol. Through March 2003, MCG reports that 43 percent of the fuel used for these vehicles was ethanol. At the Gaithersburg depot, where drivers have access to ethanol or gasoline, 85 percent of the fuel used is ethanol. MCG is working to improve user compliance. (See Appendix F ©47 for MCG's ethanol usage report.)

MCG makes every effort to find flexibly fueled vehicles. However, the vehicles must meet the needs of the user department and be a cost effective alternative. The choices are limited because flexibly fueled vehicles are only available in some classes of vehicles. In the past two years, prices for flexibly fueled models have been comparable to the gasoline models; however, this could change in the future.

In addition to the light duty fleet, DPWT has expanded the use of CNG buses by seeking federal, state, and county funding. In FY 03, MCG operates 24 buses that are fueled with CNG. These vehicles traveled 1.2 million miles and produced 13.8 tons of pollutants in FY 2002. In FY 2004, MCG will expand the current fleet of 24 CNG buses by 33 buses; bringing the total fleet to 57 CNG buses. Some of these buses will replace all of the pre-1991 diesel transit buses. These new CNG buses will produce six times less NO_X, three times less VOC, and 56 times less PM per mile than the buses which are being replaced.

By FY 2005, MCG will have 79 CNG buses. All of the pre-1994 diesel buses will be replaced and CNG buses will represent over 20 percent of the total Ride on fleet. MCG is building a CNG fast fill station, which can accommodate 79 buses. Until the station opens, the fueling limitations require the CNG buses to operate on a split block. This means the CNG buses operate in the morning and evening rush hours and come back to the depot in the middle of the day to refuel. In contrast, a diesel bus can stay in operation all day without refueling. Presently the CNG fleet, which is fueled out of Gaithersburg, runs only on routes which serve areas north of White Flint and Twinbrook.

The approved FY 04-10 Capital Improvements Program includes a facility planning project that would increase the capacity of the CNG fueling station to 200 buses and allow the buses out of the Gaithersburg depot to be entirely fueled with CNG. Space limitations prohibit the installation of a CNG fueling station at the Brookeville (Silver Spring) depot, which serves the down-County area. Over the long term, MCG plans to investigate the option of hybrid electric buses for downcounty routes.

G. Use diesel fuel additives or ultra low sulfur diesel fuel

The majority of heavy duty vehicles on the road today are powered by diesel engines. [8] Although diesel engines are highly reliable and more fuel efficient compared to gasoline engines, they emit significant amounts of particulate matter and nitrogen oxides.

Use of diesel fuel additives. Marketed as a low cost, short-term solution for addressing emission issues, fuel additives do not require any engine hardware modifications, specialized infrastructure or new equipment.

[8] According to a study completed for the Diesel Technology Forum, "diesel engines provide the power to move 94% of all freight in the U.S. and 95% of all transit buses and heavy construction machinery." Clean Air: Trucking's Contribution, "Diesel engines will remain the predominant power source for commercial trucks," December 10, 2001.

The fuel additive 'Proformix' is an example of a diesel fuel additive that reduces particulate matter (PM) and nitrogen oxide (NO_X) emissions. A 2001 study for the California Air Resources Board (CARB) reported Proformix produced a 14 percent reduction in NO_X and a 63 percent reduction in PMs. The additive can be used in old and new diesel engines and costs an additional five to ten cents per gallon.

EPA has certified this fuel additive for use in Houston, Texas. The state of Maryland reports that testing of the additive in Maryland uncovered problems with coagulation in cold weather.

Use of ultra low sulfur diesel fuel. Diesel fuel contains different levels of sulfur, which can affect vehicle emissions. Sulfur levels for on-road vehicles across the country range from 350 to 500 parts per million (ppm).[9]

- Regular diesel fuel (referred to as low sulfur diesel fuel) has a sulfur level of 300 parts per million.

- Clean or green diesel fuel (referred to as ultra low sulfur diesel fuel) has a sulfur content of 15 to 30 parts per million.

The use of ultra low sulfur diesel fuel reduces particulate matter emissions because sulfate, which is a major component of particulate matter, is a byproduct of burning diesel fuel with sulfur. It does not affect the emissions of nitrogen oxide or hydrocarbons. Currently, the availability of ultra low sulfur diesel fuel is limited; it is available in California, the Northeastern states, Washington, D.C., and Houston, Texas.

In June 2006, EPA regulations will limit the amount of sulfur in diesel fuel to 15 parts per million, nationally. Between June 2006 and June 2010, the 80/20 rule will allow up to 20 percent of highway diesel production to continue at the current limit of 500 ppm. Refiners expect the cost of ultra low sulfur diesel to be approximately ten cents a gallon more than the cost of low sulfur diesel.

Examples of transit fleets already using ultra low sulfur diesel fuel include:

- The Washington Metropolitan Area Transit Authority (WMATA) – In October 2001, WMATA switched its entire diesel bus fleet to ultra-low sulfur diesel fuel. WMATA estimated that the use of ULSD for a fleet of 1,443 buses would reduce PM emissions by 25 percent or 16.9 tons per year and the increased fuel cost would be $1.44 million annually for a pollution savings cost of $85,207 per ton. Today, WMATA staff report there have been no problems with leaking seals on older buses using ULSD and that using ULSD does not void bus manufacturer warranties. For the period of May 19 to June 1, 2003, WMATA reports that the cost of USLD was approximately ten cents per gallon more than regular diesel:

9 The sulfur content in off-road diesel can be as high as 5,000 ppm. See page 54 for details.

- New York City Transit – New York City's bus transit fleet (with and without pollution control devices) runs on ultra-low sulfur diesel fuel. Results from a NYC Transit study show that in one year 50 buses emitted 29 percent less particulate matter.

- King County, Washington - King County uses ultra-low sulfur diesel in their transit fleet, heavy duty trucks, and off-road equipment since July 2001.

Industry experts believe the use of ultra low sulfur diesel will lead to the continued improvement of pollution control devices on heavy duty diesels. Pollution control devices require ultra low sulfur fuel for optimal performance.

County and bi-County agency practices. None of the agencies currently uses ultra low sulfur diesel fuel because the cost is estimated to be five to ten cents per gallon higher than regular low sulfur diesel, plus an additional penny per gallon for the cost of an additive which is needed to improve the lubricity. OLO estimates the additional cost of ultra low sulfur fuel would range from $315,000 to $630,000 across the five agencies, assuming an annual consumption of at least 6.3 million gallons.

MCPS and M-NCPPC staff see the use of ultra low sulfur diesel as a promising strategy for reducing emissions. MCPS staff expressed concerns about how the use of ultra low sulfur diesel fuel would affect the warranties it purchases for its engines and the availability of the fuel. MCG staff raised concerns about the increased costs.

H. Retrofit existing diesel engines

Diesel engines can remain in service for hundreds of thousands of miles, be rebuilt and put back in service for many years. The practice of rebuilding a diesel engine provides an opportunity to "retrofit" or install pollution control devices.

Pollution control equipment or "after-treatment technologies" capture or convert emissions before exhausted into the air. Proven retrofit devices that control particulate matter, volatile organic compounds, and carbon monoxide include diesel oxidation catalysts and diesel particulate filters.

Retrofit devices emerging as proven controllers of NO_X include exhaust gas recirculation (EGR), selective catalytic reduction (SCR), and lean NO_X catalysts. In some cases, diesel oxidation catalysts and diesel particulate filters can be combined with EGR to control both PM and NO_X. Exhibit 33 provides a summary of emission reductions and costs associated with the pollution control devices. (Appendix G ©48 provides more details on these and other devices.)

EXHIBIT 33: SUMMARY OF POLLUTION CONTROL DEVICES FOR ON-ROAD DIESEL VEHICLES*

Pollution Control Device	PM Reduction	VOC Reduction	NO_X Reduction	Stage of Development	Cost**
Diesel Oxidation Catalyst	25% to 50%	70%	No reduction	Available	$425 to $1,750
Diesel Particulate Filters	At least 85%	90%	No reduction	Available	$7,500
Exhaust Gas Recirculation	No reduction	No reduction	At least 40%	Available, but not widely used in U.S.	$13,000 to $15,000
Lean NO_X Catalyst	No reduction	No reduction	10% to 20%	Under development	Cost Not available
Selective Catalytic Reduction	30% to 50%	50% to 90%	55% to 90%	Available, but not widely used in U.S.	$10,000 to $50,000

Source: MECA, March 2002

* All technologies require Ultra Low Sulfur Diesel. **Cost is dependant on the size of the engine.

According to the Manufacturers of Emissions Controls Association (MECA), a successful diesel retrofit program identifies the:

- Vehicles suitable for pollution control devices;
- Appropriate pollution control device;
- Desired emission reductions;
- Availability of ultra-low sulfur diesel;
- Operational and maintenance requirements of the device; and
- Training and education needs of the mechanics responsible for installing the devices.

In sum, fleet managers must weigh both upfront capital investment costs as well as ongoing operating fuel and maintenance costs of installing a device. For example, a fleet manager might determine it more cost effective to replace a vehicle than install a pollution control device.

EPA has established three programs to promote the retrofit of diesel engines: the Urban Bus Retrofit/Rebuild Program, the Voluntary Diesel Retrofit Program, and, most recently, the Clean School Bus program

- In the mid 1990s, Congress established the Urban Bus Retrofit/Rebuild program in law. This program is mandatory for transit agencies in metropolitan areas with populations of 750,000 or more. It requires jurisdictions to retrofit any bus manufactured in 1993 or earlier with pollution control technology certified by EPA.

- The Voluntary Diesel Retrofit Program is intended to help fleet owners and manufacturers reduce emissions. EPA funds pilot projects to install, verifies retrofit technologies, and provides technical assistance to fleet owners and managers. Examples of current program participants include: San Diego Unified School District, which retrofitted 30 diesel buses in 1999; New City Transit, which retrofitted 50 NYC transit urban buses; King County, which has 800 buses awaiting retrofit; and the City of Seattle, which retrofitted heavy duty diesels beginning 2001. See Appendices H and I, © 76 and © 78, for more program information and for results of these pilot programs.

- In the spring of 2003, EPA announced the establishment of the Clean School Bus USA program. This program will provide grants to retrofit school buses to reduce children's exposure to harmful diesel emissions. EPA plans to issue a request for awards in June (2003) to fund school bus retrofit projects. EPA hopes to award five to ten school districts grants between $500,000 to $1,000,000.

County and bi-County agency practices. County agencies have limited experience with retrofit strategies. In the early 1990's, MCG had a pilot program to retrofit buses with particulate traps. MCG reports that because the buses had maintenance and operating problems, the particulate traps were removed.

MCG also participated in EPA's Urban Bus Retrofit/Rebuild program. The Washington metropolitan area, including Montgomery County, is one of the 49 areas across the United States covered by this program. MCG reports that 41 of the 51 1990 to 1993 Orion buses currently in the fleet had engine replacements that complied with the Urban Bus Retrofit Program standards at a cost of $20,000 per bus. There was a $3,145 cost difference between the pre-1994 engine and the refitted engine which met the new standards.

VI. Agencies' Off-Road Equipment Inventory

The EPA mobile source category includes on-road vehicles and off-road vehicles, equipment and engines. This chapter discusses the affect of off-road equipment emissions on air quality and reviews existing and proposed regulatory requirements. The chapter also summarizes the agencies' inventory of off-road equipment.

A. Background

The term "off-road" refers to vehicles, equipment, and engines fueled by diesel and gasoline. Examples include (but are not limited to) lawnmowers, chainsaws, boat motors, tractors, generators, and bull dozers.

Emission standards for off-road engines did not exist prior to 1996 and remain less stringent than on-road vehicles. Consequently, EPA and industry experts report that off-road engines are a significant source of urban air pollution. Lawn/garden and construction equipment, specifically, emit large amounts of nitrogen oxide (NO_X), volatile organic compounds (VOC), carbon monoxide (CO), and particulate matter (PM).

A typical pre-1997 lawn mower can emit the same amount of ozone forming pollutants in an hour as a new car driven 340 miles. Exhibit 34 provides examples of other emission comparisons between off-road equipment and a typical passenger car. These comparisons are particularly alarming given that about 35 million small off-road engines are sold annually in the U.S. compared to about 15 million cars and light trucks.

EXHIBIT 34: EMISSIONS FROM OFF-ROAD EQUIPMENT RELATIVE TO A TYPICAL PASSENGER CAR

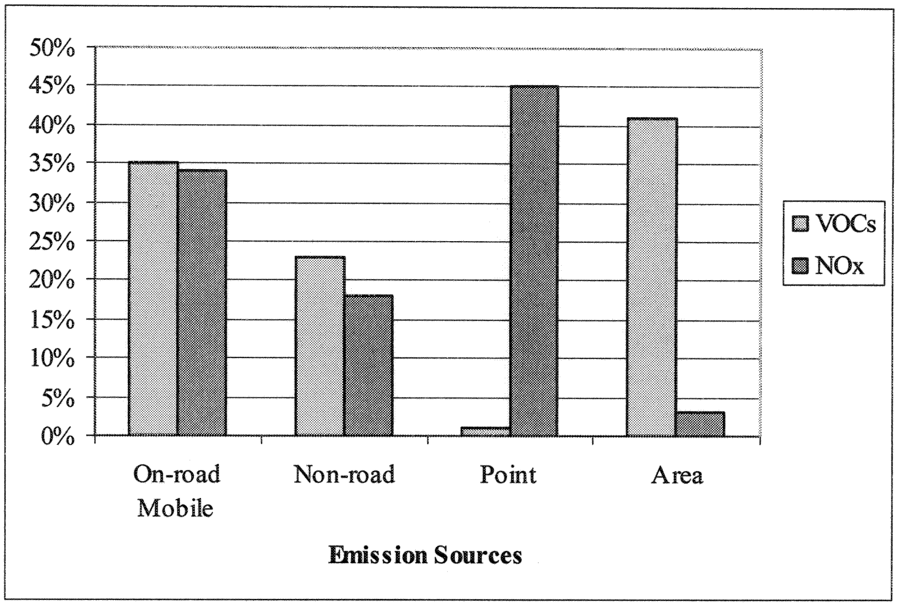
1 Hour of Use	Pollutant	Car Miles
1 chain saw	VOC	200
1 outboard motor	VOC	800
1 Tractor	NO_X	900

Source: EPA

In addition, EPA estimates that diesel engines (especially the heavy duty diesel engines in bulldozers, backhoes, and loaders) account for about 44 percent of diesel particulate matter emissions and about 12 percent of NO_X emissions from mobile sources nationwide. In Montgomery County, off-road engines (referred to as non-road engines) emit approximately 20 percent of the total ozone forming pollutants (see Exhibit 35 page 51).[1]

[1] DEP calculated the emissions from non-road engines by using a formula based on population.

EXHIBIT 35: OZONE FORMING POLLUTANTS EMITTED BY SOURCE IN MONTGOMERY COUNTY



Source: Montgomery County DEP May, 2003

B. Existing Emission Standards for Off-Road Equipment

In 1994, EPA developed three sets of standards to regulate emissions from off-road engines. The standards regulate the maximum permissible amount[2] of NO_X, HC, NMHC + NO_X, CO, and PM emissions for various engine sizes. Exhibit 36 (page 52) shows the regulations set by the EPA. The standards exclude locomotive and marine engines. Tier 1 standards stay in effect until Tier 2 and/or Tier 3 standards take effect. The standards apply to the life of the engine, which the Clean Air Act defines as:

- Five years or 3,000 hours of use for engines less than 50 horsepower;
- Five to seven years or 3,000 to 5,000 hours of use for engines between 50 and 100 horsepower; and
- Ten years or 8,000 hours of use for engines greater than 100 horsepower.

[2] Calculated at the allowed number of grams per brake horse power or kilowatt per hour.

EXHIBIT 36: EXISTING THREE-TIERED EMISSION STANDARDS FOR NON-ROAD ENGINES*
(NO_X + VOC/PM)**

Engine Power (hp)	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013 & Beyond
<25***			7.1/0.75							5.6/0.6				
25<50		7.1/0.60								5.6/0.4				
50<100		--/--				5.6/0.30						3.5/0.3		
100<175					4.9/0.2						3.0/0.2			
175<750		--/--			4.8/0.1						3.0/0.1			
>750			--/0.40								4.8/0.1			

Source: EPA

Tier 1 Standards **Tier 2 Standards** **Tier 3 Standards**

* Engines under 11 horsepower can emit 7.8 NO_X + NMHC and 0.75 PM.
** Reported in grams per brake horsepower per hour.
***Emission standards exclude locomotive and marine engines.

Tier 1 standards apply to small engines less than 50 horsepower[3] and will be phased in from 1997 to 2005. Tier 1 standards primarily regulate emissions from lawn and garden equipment and should result in a 32 percent reduction in VOC emissions from these engines.

More stringent **Tier 2 standards** will be phased in from 2003 to 2006. The Tier 2 standards reduce emissions from engines over the size of 50 horsepower. The standards also further reduce the Tier 1 emission standards for small engines (less than 50 hp). EPA expects Tier 2 standards to reduce both VOC and NO_X emissions by 59 percent in addition to the Tier 1 estimate.

Even tougher **Tier 3 standards** apply to engines between 50 and 750 horsepower and take effect between 2006 and 2008. EPA hopes the Tier 3 standards lead manufacturers produce new engines with advanced emission control technologies (e.g., catalytic converters).

C. Proposed Engine and Fuel Standards for Off-Road Equipment

EPA plans to introduce in 2008, new Tier 4 standards to reduce emissions of PM and smog forming pollutants from off-road engines. The proposal also reduces the level of sulfur in "off-road" diesel fuel. EPA proposes to phase in the standards over a two or three year period and target heavy duty diesel engines. Exhibit 37 (below) shows when the new Tier 4 emission standards will take effect.

EXHIBIT 37: PROPOSED TIER 4 EMISSION STANDARDS FOR NON-ROAD ENGINES (NO_X + NMHC/PM*)

Engine Power (hp)	2008	2009	2010	2011	2012	2013 & Beyond
<25	**NA/0.3**					
25<75	**5.6-7.1/0.4-0.6**					**3.5/.02**
75<175	**3.0-4.9/0.2-0.3**				**0.44/.01**	
175<750	**3.0/0.1**			**0.44/.01**		
>750	**4.8/0.1**			**0.44/.01**		

Source: EPA

*Reported in grams per brake horsepower per hour.

Previous Standard

Tier 4

[3] Standards for PM emissions for engines between 600 and 750 horsepower are also included in Tier 1 standards.

Proposed Reduction of Sulfur levels in Off-Road Diesel Fuel. Today, highway diesel fuel used in trucks and buses must not contain more than 500 parts per million (ppm) of sulfur. Federal regulations require that the level of sulfur be further reduced to 15 ppm by mid 2006. The benefits of ultra low sulfur fuel (15 ppm) include:

- A reduction in the emission of PM and dangerous sulfate particles; and
- An increase in the effectiveness of emission control systems.

In contrast to highway diesel, off-road diesel fuel standards allow 5,000 ppm in sulfur content, or ten times the amount allowed in highway diesel fuel. EPA proposes to match off-highway standards with current on-highway diesel standards. The proposal calls for the use of low-sulfur diesel (500 ppm) starting in 2007 and ultra-low sulfur diesel (15 ppm) in 2010.

When fully implemented, EPA believes that the new engine and fuel standards should reduce ozone forming pollutants and particulate matter emitted by non-road engines by 70 percent (or an estimated 825,000 tons of NO_X and 125,000 tons of PM annually). Also, EPA estimates that by 2030 the integration of engine and fuel controls for off-road diesel engines will, annually prevent over:

- 9,600 premature deaths;
- 8,300 hospitalizations;
- 16,000 heart attacks;
- 5,700 children's asthma-related emergency room visits;
- 260,000 respiratory problems in children; and
- A million work days lost due to illness.

EPA believes that the proposed standards will increase engine prices by about 23 percent initially. EPA also expects that the initial price of off-road equipment will increase by about 5.2 percent. The average price increase for off-road diesel fuel for all years is expected to be about 4.1 percent. The EPA is currently accepting comments on its proposal until August 20, 2003 and public hearings are set to start in June 2003.

Available Methods of Controlling Emissions. The technology to control exhaust emissions from off-road diesel engines has been in use for decades. The mining industry leads the way in using control devices to help meet the occupational health needs of miners. Mining companies use emission control devices on both small and large diesel engines.

The Manufacturers of Emission Controls Association (MECA) identifies two proven technologies commonly used since 1986 to control emissions from diesel engines:

- Diesel Particulate Filters; and
- Diesel Oxidation Catalysts.

Diesel Particulate Filters significantly reduce the amount of particulate matter and hydrocarbons in diesel exhaust. According to MECA, the filters can remove 50 to 90 percent of particulate matter and hydrocarbons from exhaust emissions. The filters are more efficient when low sulfur fuel is used. The technology can be applied to both large and small diesel engines and costs $10,000 to $13,000 per engine. Diesel particulate filters do not reduce the level of NO_X emissions.[4]

Diesel Oxidation Catalysts reduce PM, CO, and HC emissions. Research shows that the catalysts reduce PM and HC emissions (tested with ultra low sulfur fuel) by 50 percent. The technology has been used on engines greater than 75 horsepower. The device (when properly maintained) has a life of thousands of operating hours. The catalysts, which provide modest PM emission reductions compared with the filters, cost $2,500. However, like the filters, diesel oxidation catalysts do not reduce NO_X emissions.[4]

In 1998, the Massachusetts Turnpike Authority (MTA) implemented a diesel retrofit program to place diesel oxidation catalysts on 25 percent of the long-term off-road diesel equipment used in constructing Boston's "Big Dig" project. MTA contributed 50 percent of the cost or about $1,200 per device. Due to positive air quality results from the program, MTA now requires that all off-road diesel equipment used until the end of the project must have oxidation catalysts. MTA estimates that each year the catalysts will reduce 36 tons of CO, 12 tons of HC, and 3 tons of PM. In addition, contractors are required to:

- Keep equipment properly tuned;
- Turn off diesel combustion engines on equipment not in active use; and
- Locate construction equipment away from fresh air intakes to buildings, air conditioners, and windows.

Montgomery County Department of Environmental Protection (DEP) Initiatives. On April 27, 2003 DEP sponsored a lawn and garden equipment rebate and exchange program at the Household Hazardous Waste Collection site at the Upcounty Regional Service Center. The program encourages residents to trade in old:

- Gas powered lawn mowers for a reel push mower;
- Gas powered trimmers and leaf blowers for electric models; and
- Gas cans for a free no-spill gas can.

Residents receive a $50 rebate check for a "reel" push mower and a $25 rebate check for electric leaf blower/trimmer. See Appendix K at ©101.

[4] Devices to control NO_X emissions from non-road engines are not in widespread use. See Appendix L at ©102 for more information on the available/emerging technologies.

B. Off-Road Inventory by Agency

Introduction. As part of this project, OLO worked with agency staff to compile an inventory of off-road equipment. This section presents the inventory of off-road gas and diesel equipment maintained by:

- Washington Suburban Sanitary Commission (WSSC);
- Montgomery County Public Schools (MCPS);
- Montgomery College (MC);
- Maryland-National Capital Park and Planning Commission (M-NCPPC); and
- Montgomery County Government.

OLO appreciates the efforts of agency staff to compile the list of equipment. Generally, OLO believes that the inventory is an accurate account of off-road equipment maintained by the agencies in FY 02. OLO was unable to determine whether the inventory reported for MCG represents the universe of off-road engine equipment. OLO feels that the inventory reported for MCG appears to be low, compared to the other agencies.

Using a classification system developed by the EPA, OLO classified the inventory into the following seven categories:

Equipment Category	Examples
Lawn and Garden	lawn mowers, lawn tractors, leaf blowers, trimmers, edgers, leaf vacuums, root/sod cutters, chainsaws
Recreational	golf carts, all-terrain-vehicles, inboard and outboard motors
Commercial/Industrial	compressors, welders, generators, pumps, aerial lifts, forklifts, sweepers
Construction	backhoes, loaders, asphalt kettles, cement mixers, excavators, rollers
Agricultural	large tractors, harvesters, large chainsaws

The Inventory. County agencies maintain the full gamut of off-road equipment; ranging from very small two-stroke gas operated engines (e.g., edgers and lawn mowers) to heavy-duty diesels such as bulldozers, excavators, and backhoes.

The exhibits on pages 58 and 59 depict the distribution of equipment by agency, fuel type, and equipment category. In sum:

- The five agencies maintain a total of 4,469 pieces of off-road engine equipment. Gas operated equipment comprises 83 percent (or 3,691 pieces) of the total and diesel fueled equipment accounts for the remaining 17 percent (or 778 pieces).

- M-NCPPC's and MCPS's inventory of off-road engines combined represent over two-thirds of the total inventory. Of the two agencies, M-NCPPC maintains the greatest number of off-road equipment; accounting for 1,647 (or 37 percent) of the total inventory. MCPS maintains slightly over 1,500 pieces of equipment; accounting for 34 percent of the total.

- WSSC's inventory also constitutes a substantial share; accounting for nearly one-quarter (21 percent) of the total inventory.

- Two agencies split the remaining eight percent of the 4,469 pieces of equipment: MCG maintains 227 pieces and MC maintains 128 pieces.

- With the exception of WSSC, lawn and garden equipment represents a significant proportion of each agency's off-road equipment inventory. Lawn mowers, edgers, trimmers, chainsaws, sod cutters, etc., account for:

    - 97 percent of MCPS' inventory;
    - 73 percent of MC's inventory;
    - 65 percent of M-NCPPC's inventory; and
    - 41 percent of the MCG's inventory.

- Commercial and industrial equipment represent the second greatest portion (17 percent) of the inventory across the agencies. WSSC maintains the greatest number of commercial and industrial pumps, generators, and compressors.

- The five agencies combined maintain 293 heavy-duty diesels e.g., loaders, bulldozers, excavators, rollers, tractors, and graders. WSSC maintains the greatest number (267) of diesel engines, including 51 backhoes, 19 loaders, two excavators, and two bulldozers.

EXHIBIT 38: OFF-ROAD EQUIPMENT INVENTORY

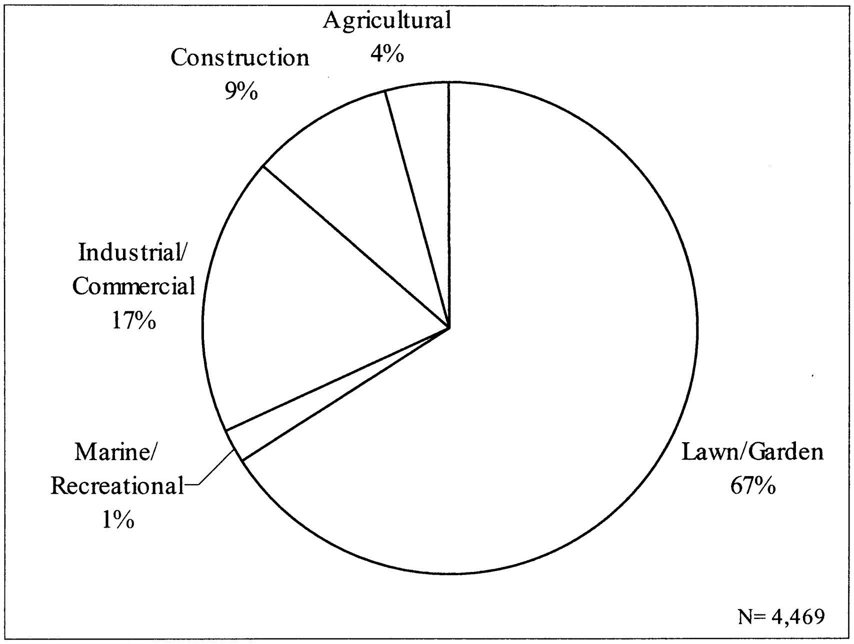
Agency	Categories of Gas Operated Equipment					Total
	Lawn/Garden	Recreational	Commercial/Industrial	Construction	Agricultural	
Park and Planning	972	78	254	25	85	1,414
MCPS	1,387	0	7	19	0	1,413
WSSC	214	13	327	138	1	693
County Government	27	0	12	15	3	57
Montgomery College	85	16	8	5	0	114
Total	**2,685**	**107**	**608**	**202**	**89**	**3,691**

Agency	Categories of Diesel Operated Equipment					Total
	Lawn/Garden	Recreational	Commercial/Industrial	Construction	Agricultural	
Park and Planning	97	0	10	47	79	233
MCPS	75	0	0	15	4	94
WSSC	4	0	172	83	10	267
County Government	67	0	28	71	4	170
Montgomery College	9	0	1	4	0	14
Total	**249**	**0**	**211**	**218**	**97**	**778**

Agency	Combined Gas and Diesel Equipment Categories					Total
	Lawn/Garden	Recreational	Commercial/Industrial	Construction	Agricultural	
Park and Planning	1,069	78	264	72	164	1,647
MCPS	1,462	0	9	34	4	1,507
WSSC	218	13	499	221	11	960
County Government	94	0	40	86	7	227
Montgomery College	94	16	9	9	0	128
Total	**2,934**	**107**	**819**	**420**	**186**	**4,469**

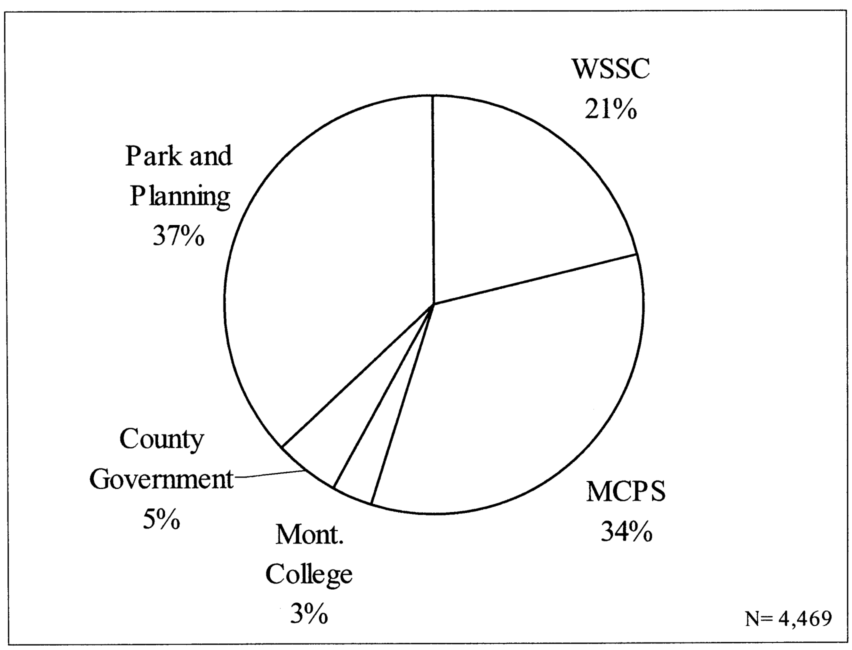
Source: OLO, May 2003

EXHIBIT 39: DISTRIBUTION OF OFF-ROAD EQUIPMENT BY EPA CATEGORIES



Source: OLO, May 2003

EXHIBIT 40: DISTRIBUTION OF OFF-ROAD EQUIPMENT BY AGENCY



Source: OLO, May 2003

The Dirtiest Polluters. The five agencies maintain a total of 778 diesel engines. Exhibit 41 (page 61) shows that over one-third of these engines (293) are considered heavy duty diesels – the worst polluters among off-road engines. The remaining two-thirds comprise mainly of diesel mowers, street sweepers/vacuums, compressors, and generators. These diesel engines utilize low sulfur fuel, but are not equipped with emission control. However, most of the diesel engines receive preventive maintenance and corrective maintenance, which helps engine performance.

In order to significantly reduce PM and VOC emitted from off-road diesel engines, agencies would need to either replace equipment or retrofit engines with pollution control devices such as diesel particulate filters and diesel oxidation catalysts. Exhibit 41 (page 61) compares the cost differential between these two devices for each agency's fleet of off-road diesel engines. As shown, OLO estimates it would cost $2 million to purchase diesel oxidation catalysts or $10 million to purchase diesel particulate filters for the 778 diesel engines.

Pre-1997 lawn and garden equipment also contributes significantly to urban air pollution, as explained on page 50. OLO found more than half of the equipment at each agency was purchased before tighter EPA emission standards took effect. Specifically, 92 percent of WSSC's lawn and garden equipment and nearly 60 percent of the MCG's lawn and garden equipment was purchased before 1997. Fleet staff from MCPS, M-NCPPC, and MC believe that up to three-quarters of their lawn and garden inventory consists of pre-1997 equipment.

The consensus among agency staff is that most lawn/garden equipment has a useful life of five to seven years, which means that much of this equipment will be replaced through attrition in the next few years.

EXHIBIT 41: SUMMARY OF COMMONLY USED DIESEL ENGINES

Equipment	County Government	MCPS	WSSC	Park & Planning	Montgomery College	Total
Heavy Duty Diesel Engines						
Excavators	9	3	2	0	0	**14**
Graders	2	0	0	1	0	**3**
Loaders	28	7	19	24	1	**79**
Rollers	19	0	0	2	0	**21**
Backhoes	0	5	51	19	1	**76**
Bulldozers	0	0	2	0	0	**2**
Tractors	4	4	10	78	2	**98**
Sub-Total	**62**	**19**	**84**	**124**	**4**	**293**
Other Diesel Engines						
Mowers	1	70	4	97	8	**177**
Forklifts	3	0	8	3	0	**16**
Sweepers/ Vacuums	56	0	1	0	0	**57**
Compressors	0	0	69	0	0	**69**
Generators	0	0	52	0	0	**52**
Other	48	1	49	9	2	**113**
Sub-Total	**108**	**71**	**183**	**109**	**10**	**484**
Total	**170**	**90**	**267**	**233**	**14**	**778**

Source: OLO, May 2003

EXHIBIT 42: ESTIMATED COSTS OF INSTALLING POLLUTION CONTROL DEVICES ON OFF-ROAD DIESEL EQUIPMENT

Estimated Cost to Retrofit Fleet:*						
Diesel Oxidation Catalysts	$425	$225	$668	$583	$35	$1,9368
Diesel Particulate Filters	$2,210	$1,170	$3,471	$3,029	$182	$10,062

Source: OLO, May 2003

*Amounts reported in ($ in 000's)
** Based on $2,500 per Diesel Oxidation Catalyst
***Based on $13,000 per Diesel Particulate Filter

VII. Findings

Montgomery County has some of the most polluted air in the country. Montgomery County citizens face a cancer risk more than 100 times the goal set by the Clean Air Act. The American Lung Association reports that almost half of the County's citizens, including children, seniors, and people who suffer from asthma, bronchitis and emphysema, face even higher risks.

In January 2003, the Environmental Protection Agency (EPA) classified the Washington metropolitan region as a severe nonattainment area for ozone. By March 1, 2004, the states of Maryland and Virginia and the District of Columbia are required to submit revised "State Implementation Plans (SIPs)," which identify the actions each jurisdiction will take to reduce emissions and come into compliance with the Clean Air Act. The Clean Air Act requires EPA to impose sanctions on jurisdictions in nonattainment areas that do not submit or implement adequate plans. These sanctions could include the imposition of a two to one offset for new (and modified) sources of emissions and the withholding of federal highway funds.

In light of this situation, the County Council asked OLO to examine how the five County and bi-County agencies (the agencies) manage the emissions of their vehicle and equipment fleets. According to the forthcoming Montgomery County Environmental Policy, the Council believes the County must "lead by example," although the public agency fleets represent a mere fraction of the region's vehicles and equipment.

This chapter summarizes the findings from OLO's study of the vehicle and equipment fleets of the Montgomery County Government (MCG), the Montgomery County Public Schools (MCPS), Montgomery College (MC), the Maryland National Capital Park and Planning Commission (M-NCPPC), and the Washington Suburban Sanitary Commission (WSSC).

- Part A presents key characteristics of the agencies on-road vehicle fleets (cars, trucks, and buses) as a whole and identifies variables that affect vehicle emissions,
- Part B reviews the emission inventories of the agencies' vehicle fleets,
- Part C presents promising strategies currently available to reduce vehicle emissions
- Part D reports on the agencies' practices to control vehicle emissions,
- Part E identifies the agencies' challenges to reducing emissions, and
- Part F summarizes information about the agencies' gasoline and diesel powered off-road equipment, e.g., lawn mowers, chain saws, bulldozers.

Unless otherwise indicated, all data references to the agencies' vehicle and equipment fleets owned and operated in FY 02 reports only those vehicles for which OLO had mileage and emission factors. The particulate matter estimates do not reflect the retrofits to 41 pre-1994 transit buses.

A. Characteristics of the Agencies' Vehicle Fleets (Cars, Buses, and Trucks)

Finding #A1: The five agencies own approximately 6,000 vehicles that, during FY 02, collectively traveled more than 75 million miles and consumed nearly 10 million gallons of fuel. The inventory varies significantly across agencies, reflecting the diversity of each agency's unique service needs.

- MCG maintains the largest vehicle fleet among the five agencies. MCG's light and heavy duty fleets include 1,506 passenger cars, 389 light trucks, and 589 heavy trucks. The County owns 80 percent of the passenger cars and half of the heavy trucks operated by the five agencies combined. MCG's light and heavy duty vehicles traveled 27.9 million miles in FY 02 and 322 transit buses traveled 13.4 million miles in FY 02.

- MCPS maintains the second largest fleet among the five agencies. MCPS' inventory contains 100 passenger cars, 243 light trucks, 221 heavy trucks, and 1,113 school buses. In FY 02, MCPS' school buses traveled 18.7 million miles, while the agency's light and heavy duty fleet vehicles traveled 3.4 million miles.

- WSSC's vehicle fleet contains 871 vehicles: 122 passenger cars, 568 light trucks, and 181 heavy trucks. In FY 02, WSSC's vehicles traveled 8 million miles. WSSC maintains 40 percent of the light trucks owned by the five agencies combined.

- M-NCPPC's vehicle fleet contains 528 vehicles: 154 cars, 198 light trucks, and 176 heavy trucks. In FY 02, these vehicles traveled 4.6 million miles.

- Montgomery College's vehicle fleet contains 44 vehicles: one passenger car, 21 light trucks, and 22 heavy trucks. In FY 02, these vehicles traveled 185,000 miles.

Finding #A2: The Montgomery County fleet consists of transit buses, school buses, heavy trucks, light trucks, and passenger cars. Passenger cars and light trucks account for 55 percent of the fleet. Buses account for a quarter of the fleet, and heavy trucks the remaining 20 percent.

- Transit buses represent six percent of the vehicles owned by the five agencies and accounted for 18 percent of the total vehicle miles traveled in FY 02.

- School buses represent 19 percent of the vehicles owned by the five agencies and accounted for 24 percent of the total vehicle miles traveled in FY 02.

- Heavy trucks represent 20 percent of the vehicles owned by the five agencies and accounted for nine percent of the total vehicle miles traveled in FY 02. MCG owns 596, or about half of the 1,188 heavy trucks owned by all five agencies.

- Light trucks represent 24 percent of the vehicles owned by the five agencies and accounted for 18 percent of the total vehicle miles traveled in FY 02. WSSC owns 568 or about 40 percent of the 1,420 light trucks owned by all five agencies.

- Passenger cars represent one-third of the vehicles owned by the five agencies and accounted for 31 percent of the total vehicle miles traveled in FY 02. The County government operates 1,506 or 80 percent of the 1,883 passenger cars owned by all give agencies. (1,173 of MGC's passenger vehicles are police and sheriff vehicles.)

Finding #A3: Larger vehicles pollute at a higher rate than smaller vehicles. For example in the Montgomery County fleet OLO determined that:

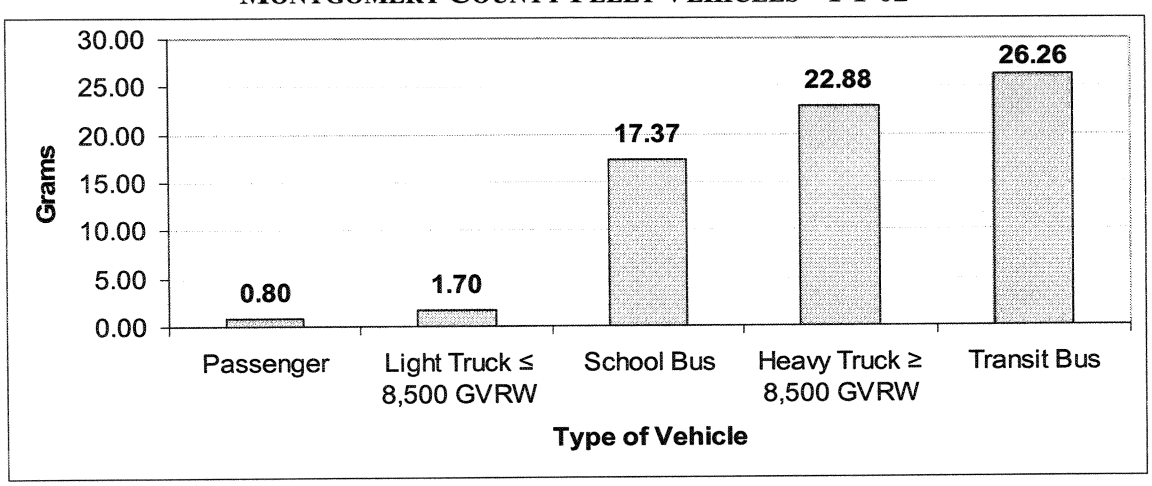
- A transit bus emits 26.26 grams per mile,

- Heavy trucks emit 22.88 grams per mile,

- Diesel school buses emit 17.37 grams per mile, and

- Light trucks emit 1.7 grams per mile or twice the rate of a passenger car.

EXHIBIT 43: AVERAGE RATE OF POLLUTANTS RELEASED PER MILE TRAVELED BY MONTGOMERY COUNTY FLEET VEHICLES – FY 02



Source: OLO, May 2003

Finding #A4: Older vehicles pollute at higher rates than newer vehicles. As a result, the age distribution of a fleet affects the total amount of emissions.

EPA emission standards have become more stringent over time. As a result, newer vehicles pollute less than older vehicles. For example:

- A diesel transit or school bus built in 1989 emits nitrogen oxide at more than twice the rate of a bus built since 1991.

- A diesel transit or school bus built before 1991 emits particulate matter at more than twice the rate of buses built between 1991 and 1993 and at five times the rate of a bus built since 1994.

- A 1989 model year heavy truck emits nitrogen oxides at more than twice the rate of a 1991 model year truck.

- A passenger car or light truck manufactured built before 1994 emits pollutants at twice the rate of a vehicle built since 1994.

Finding #A5: Across the five agencies, there are 466 highly polluting pre-1991 buses and heavy trucks. Almost one-fourth of the combined school and transit bus fleet consists of older (pre-1994) buses.

- MCPS owns 120 pre-1991 buses, which represent 11 percent of its bus fleet. It operates an additional 142 buses, built between 1991 and 1993.

- MCG operates 17 pre-1991 buses, which represent four percent of its bus fleet. MCG operates an additional 50 buses built between 1991 and 1993.

- Of the 1,188 heavy trucks across the five agency fleets, 331 were built in 1990 or before. Together, MCG and MCPS maintain three-quarters of these older vehicles: MCG owns 151 trucks and MCPS owns 98.[3]

- Approximately 12 percent of the light duty trucks and passenger cars across the five agencies are pre-1994 vehicles.

[3] Three MCPS departments (Supply, Maintenance and Transportation) use eight 1984 to 1987 school buses in place of heavy trucks. These buses are counted in the heavy truck totals.

Finding #A6: Alternatively-fueled vehicles emit pollutants at lower rates than light duty vehicles fueled with gasoline or heavy duty trucks and school buses fueled with diesel fuel. There are 103 alternatively-fueled vehicles across the five agencies' fleets.

- MCG has 93 percent of all alternatively fueled vehicles owned by all five agencies. MCG's inventory of alternatively-fueled vehicles consists of: 60 cars and light trucks fueled by ethanol, 24 transit buses fueled with compressed natural gas (CNG), and 12 CNG sedans. The County's CNG buses account for seven percent of the transit fleet and nine percent of the transit vehicle miles traveled.

- M-NCPPC and the College each own two CNG sedans.

- MCPS owns three CNG school buses.

B. EMISSION INVENTORIES FOR THE AGENCIES' VEHICLE FLEETS

Finding #B1: Emission inventories report the amount of air pollutants for a defined geographic area or a select set of sources. Organizations produce emission inventories for different purposes.

- The Environmental Protection Agency compiles national emission inventories to monitor air quality trends. EPA also prepares emission inventory forecasts to analyze the effect of proposed regulations.

- Metropolitan planning organizations (e.g., Washington Metropolitan Council of Governments) produce regional emission inventories and emission forecasts as part of their participation in state implementation plans and air quality planning required under the Clean Air Act.

- Businesses and local governments prepare emission inventories to identify large sources of pollutants so that they can develop strategic plans to reduce emissions.

- The Cities for Climate Protection program helps local jurisdictions conduct inventories of greenhouse gas emissions in order to establish emission reduction targets. Montgomery County's Department of Environmental Protection completed an inventory of greenhouse gas emissions in January 2003 and is moving ahead to adopt target reductions.

Finding #B2: EPA emission standards have changed dramatically since they were first established in 1976. The adoption of progressively tighter emission standards for different vehicle types has been an effective strategy to reduce vehicle emissions, particularly when vehicles are replaced on a regular basis.

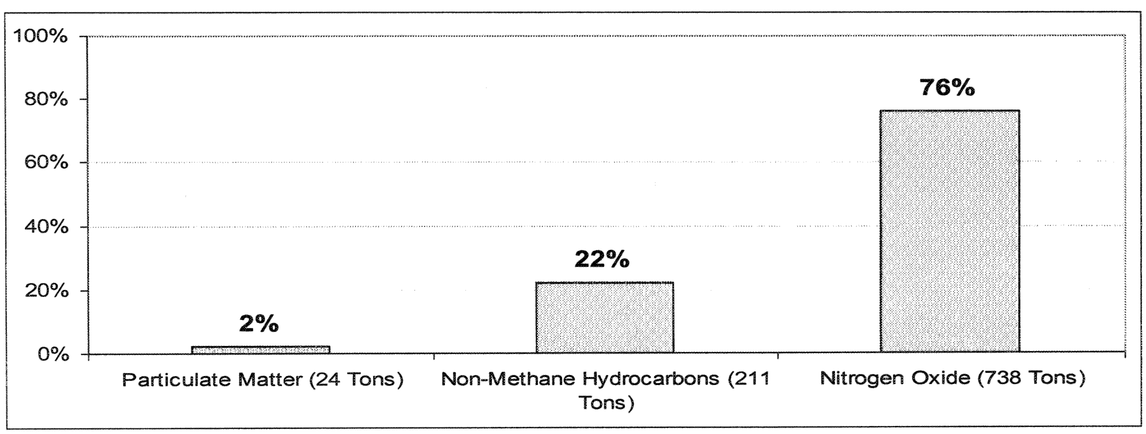
The emission estimates reported in Findings B3, B4 and B5 use emission rates based on vehicle type, weight, fuel type and annual mileage. The rates used to develop the emission inventories are based on EPA emission standards.

The Clean Air Act authorizes the Environmental Protection Agency (EPA) to establish vehicle emission standards to control pollution from mobile sources. EPA's initial efforts to establish standards focused on passenger vehicles and the first standards were established in 1976. Over time, as the emission standards from passenger vehicles declined, EPA began to target diesel engine emissions. Standards for heavy duty diesel trucks and buses were tightened in the 1990's. Increasingly strict standards are scheduled to take effect in model years 2004, 2007 and 2010.

Finding #B3: In FY 02, the agencies' on-road vehicles (cars, trucks, and buses) collectively emitted the following amount of pollutants:

- 738 tons of nitrogen oxides, a precursor of ozone (76 percent of total emissions);
- 211 tons of volatile organic compounds (22 percent of total emissions); and
- 24 tons of particulate matter (2 percent of total emissions).

EXHIBIT 44: PERCENT OF TOTAL POLLUTANTS FROM COUNTY AND BI-COUNTY AGENCY FLEET



Source: OLO, May 2003

Finding #B4: Transit buses, school buses and heavy trucks together account for 45 percent of all vehicles, 51 percent of the miles traveled, and 95 percent of the pollutants emitted by agency-owned fleet vehicles in FY 02.

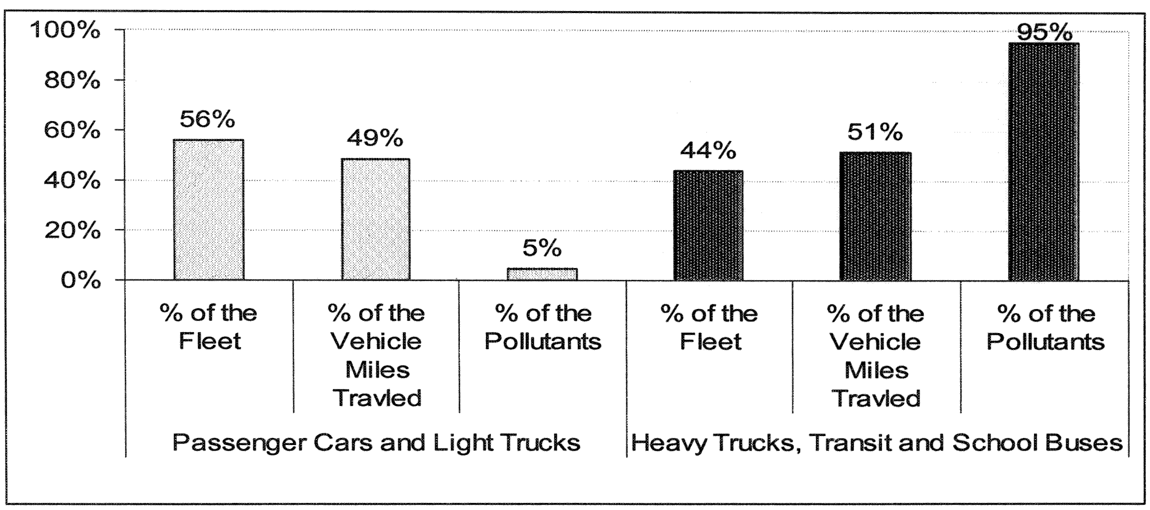
- 322 transit buses (owned and operated by MCG) account for six percent of the combined agencies' fleet and 18 percent of the miles traveled. In FY 02, transit buses produced 387 tons of pollutants, or 39 percent of all emissions.

- 1,113 school buses (owned and operated by MCPS) account for 19 percent of the combined agencies' fleet and 24 percent of the miles traveled. In FY 02, school buses produced 358 tons of pollutants or 37 percent of all emissions.

- The 1,188 heavy trucks (owned and operated by all five agencies) represent 20 percent of the combined agencies' fleet and nine percent of the miles traveled. In FY 02, heavy trucks emitted 182 tons of pollutants or 19 percent of all emissions.

- Passenger cars and light trucks (owned and operated by all five agencies) represent 56 percent of the combined agencies' fleet and 49 percent of the miles traveled. In FY 02, passenger cars and light trucks produced 46 tons of pollutants or less than five percent of all emissions.

EXHIBIT 45: SUMMARY OF COUNTY AND BI-COUNTY FLEETS – FY 02



Source: OLO, May 2003

Finding #B5. 1,361 pre-1994 vehicles account for 23 percent of the fleet, 13 percent of the total mileage and 24 percent of all pollutants emitted by agency-owned fleet vehicles; 817 of these vehicles are buses and heavy trucks, which combined emit 23 percent of all pollutants.

- 327 pre-94 buses (school and transit) account for five percent of the combined agency fleet, five percent of the miles traveled, and 15 percent of all pollutants;

- 490 pre-1994 heavy trucks account for four percent of the miles traveled and eight percent of all emissions; and

- 544 pre-94 passenger and light duty vehicles account for nine percent of the combined agency fleet, four percent of the miles traveled, and one percent of the pollutants.

C. STRATEGIES TO REDUCE FLEET EMISSIONS

Finding #C1: Promising strategies exist to reduce emissions from passenger car and light truck fleets, including:

- **Minimize fleet size;**
- **Provide preventive vehicle maintenance;**
- **Purchase fuel efficient or alternatively fueled vehicles; and**
- **Encourage conservative driving habits.**

Minimize fleet size. Limiting the size of a fleet prevents easy access to vehicles, which may in turn reduce vehicle and save fuel. After completing vehicle utilization studies, Long Beach and Oakland, California eliminated 90 to 100 under-utilized vehicles from their fleets.

Provide preventive vehicle maintenance. Preventive inspection and maintenance programs ensure vehicles operate at their maximum efficiency. Four agencies, MCG, WSSC, M-NCPPC, and the College conduct routine preventive maintenance (see finding #D1 on page 71 for details).

Purchase fuel efficient or alternatively fueled vehicles. Fuel-efficient vehicles yield lower fuel consumption and emission levels. A high efficiency vehicle can get up to 25 percent better fuel mileage than a low efficiency model within the same vehicle class. Using vehicles that operate with alternative fuels can also reduce vehicle emissions. Ethanol, compressed natural gas, and hybrid-electric propulsion provide greater fuel economy, lower fuel costs, and lower emissions than traditional fuel sources.

Encourage conservative driving habits. The driver of a vehicle can significantly affect fuel efficiency. Avoiding unnecessary driving, adhering to speed limits, and increasing speed gradually can help reduce emissions. Edmonton City, Alberta implemented a training program that provides drivers hands-on training about fuel-efficient driving. Test results show that the program yielded 20 percent savings in fuel costs. Drivers receive regular monthly feedback through reports which track fuel consumption by month, quarter and year.

Finding #C2: OLO also identified specific strategies to reduce emissions from heavy truck and bus fleets:

- **Limit idling of diesel engines;**
- **Use ultra low sulfur diesel fuel**
- **Use diesel fuel additives;**
- **Retrofit diesel engines with pollution control devices; and**
- **Replace older buses with new clean technology.**

Limit idling of diesel engines. Diesel transit buses, school buses, and heavy trucks emit substantial amounts of particulate matter and nitrogen oxides. Although more fuel-efficient than gasoline engines, a typical heavy diesel truck can still consume one gallon of fuel every hour it idles. Technology solutions exist to reduce idling time. For example, fleet managers can install block heaters to keep engines warm in cold weather.

Use ultra low sulfur diesel fuel. Reducing the level of sulfur in diesel, decreases the amount of particulate matter emitted from a diesel engine. Current regulations for highway diesel contains 500 parts per million (ppm) of sulfur. In June 2006, federal regulations will limit the amount to 15 ppm. Refiners expect the cost of ultra low sulfur diesel to be approximately ten cents a gallon more than the cost of low sulfur diesel.

Use diesel fuel additives. Marketed as a low cost, short-term solution for addressing emission issues, fuel additives do not require any engine hardware modifications, specialized infrastructure or new equipment. Additives can be used in old and new diesel engines and costs an additional five to ten cents per gallon.

Retrofit diesel engines with pollution control devices. Pollution control devices capture or convert emissions before exhausted into the air. Diesel particulate filters and diesel oxidation catalysts can be installed on existing engines; reducing particulate matter, volatile organic compounds, and carbon monoxide. According to the Manufacturers of emission Controls Association, a successful diesel retrofit program should identify the:

- Vehicles suitable for pollution control devices;
- Appropriate pollution control device;
- Desired emission reductions
- Availability of ultra-low sulfur diesel;
- Operational and maintenance requirements of the device; and
- Training and education needs of the mechanics responsible for installing the devices.

Fleet managers should weigh both upfront capital investment costs as well as ongoing operating fuel and maintenance costs of installing a device. A fleet manager may determine it more cost effective to replace a vehicle than install a pollution control device.

Replace older buses with new clean technology. Concerns about emissions from older diesel buses have created a new market for alternatively fueled buses and clean diesel buses. To date, school and transit buses fueled with CNG have emitted less nitrogen oxide and particulate matter than diesel buses. These benefits are expected to diminish in model year 2004 and disappear in model year 2007 as new EPA emission standards take effect.

In light of the more stringent emission standards and ultra low sulfur diesel, agencies should assess the emission savings gained from using alternative vehicles with new diesel buses.

D. CURRENT PRACTICES TO MANAGE THE EMISSIONS OF AGENCY-OWNED VEHICLES

Finding #D1: All five agencies rely on conventional fleet management practices to manage vehicle emissions.

Preventive maintenance and vehicle inspection programs help to ensure that vehicles operate at their maximum efficiency.

- **For passenger cars and light duty fleets, the agencies' fleet managers emphasize preventive maintenance and compliance with the State vehicle emission inspection program.** Four of the agencies (MCG, WSSC, M-NCPPC and MC) provide regularly scheduled preventive maintenance for their light and heavy duty fleets. The frequency varies by agency and vehicle type. Due to fiscal constraints, MCPS provides regular oil changes for its light duty fleet and makes repairs on an as needed basis; MCPS provides maintenance for its heavy duty fleet on an as needed basis only.

- **All of the agencies participate in the State's vehicle emission and inspection program for passenger vehicles.** MCPS and MC conduct tests at the State inspection stations. MCG, WSSC, and M-NCPPC operate in-house inspection facilities with State-certified inspectors.

- **MCG performs maintenance on heavy duty vehicles, including buses, every 6,000 miles.** This schedule means that buses receive maintenance as frequently as once a month. MCG also participates in the State's program for diesel emission testing for heavy trucks.

- **For the school bus fleet, MCPS complies with the inspection and maintenance requirements in State law.** MCPS provides three safety inspections and one preventive maintenance inspection for each bus annually. It provides an additional inspection for school buses kept beyond the replacement cycles set in State law.

Finding #D2. Four of the agencies have adopted vehicle idling policies.

Four of the five agencies (MCG, WSSC, MCPS and M-NCPPC) have policies concerning vehicle idling. These policies generally require operators to limit idling to a certain time period, e.g., to a maximum of five minutes for school buses or transit buses. WSSC's written policy requires operators to turn off motors "whenever possible." The agencies emphasize the policies in training and issue periodic reminders through newsletters or supervisors. Agency staff report that the idling policies are only enforced informally. For example, MCPS warms up the bus fleet and idles buses for to two hours. MCPS staff explain that this practice developed because MCPS has an undersized reserve bus fleet and, as a result, could not replace buses that would not restart.

Finding #D3. All five agencies have policies or practices to limit activities on Code Red/Ozone Alert days.

- MCG has written protocols that curtail operations of the Resource Recovery Facility, center line painting, lawn mowing, median strip herbicide application and asphalt paving on Code Red days. On Code Red days, MCG provides free transit services and posts signs asking employees to defer refueling of County vehicles until after 7:00 p.m.

- WSSC has a written Clean Air policy that includes procedures to follow on Code Red Day. These include: restricting fleet refueling to early morning hours, prohibiting the use of gasoline powered equipment, and prohibiting outdoor painting and facility cleaning.

- MCPS fuels its buses every day or every other day at a time chosen by each individual driver. Also, MCPS' Facilities Management and Materials Management Divisions:

    - Restrict refueling to early morning hours (whenever possible);
    - Restrict routine grass cutting and use of gasoline powered lawn maintenance equipment;
    - Require vehicle drivers to turn off engines (whenever possible);
    - Suspend outdoor painting or exterior use of materials containing volatile compounds; and
    - Re-assign employees working on outdoor activities to other duties.

- M-NCPPC defers fueling on Code Red Days; however it generally does not defer mowing because of schedule constraints.

- MC defers outside maintenance jobs and brings workers inside on Code Red Days.

Finding #D4: MCG has rebuilt 41 of its pre-1994 buses under the federal Urban Bus Retrofit/Rebuild program established by the EPA in 1995.

Through a combination of engine modifications, kit blowers and catalytic converters, these engines were remanufactured with EPA certified equipment to meet the 1994 standards for particulate emissions. As noted earlier, transit buses built in 1994 or later emit less than one fifth of the particulate matter emitted by a 1990 bus. The retrofits, which cost $20,000 per bus, resulted in significant reductions in particulate matter over time.

Finding #D5. The use of innovative practices and technologies to "green" vehicle fleets varies by agency. Although all five agencies experimented with alternatively-fueled vehicles in the early 1990's, only MCG continues to pursue this strategy. WSSC has reduced the size of its vehicle fleet as part of its overall downsizing efforts. MC is downsizing some of the vehicles in its fleet.

In the early 1990's, all five agencies tested vehicles that were converted to use compressed natural gas (CNG). Agency staff report that a variety of problems with CNG vehicles (e.g., acceleration, mechanical, and maintenance problems) led them to abandon use of many of these vehicles. Today, MCPS operates three CNG buses which are used as training vehicles. M-NCPPC and the College operate their CNG vehicles using unleaded gasoline.

Today, MCG operates the comparatively largest fleet of alternatively-fueled vehicles. MCG currently owns 60 vehicles which can be fueled with ethanol or unleaded gasoline and 12 CNG passenger cars and light trucks. MCG reports that most, if not all, of these vehicles replaced gasoline-fueled vehicles. MCG makes every effort to find competitively priced flexibly fueled vehicles that meet the needs of its user departments.

MCG also has 24 CNG buses in operation. This fleet operates upcounty and is fueled out of the CNG station at the Gaithersburg depot. OLO estimates this fleet of 24 CNG buses produces an emission savings of 20 tons of pollutants annually.

Finding #D6: MCG's plans to replace older transit buses with new cleaner buses is an effective emission reductions strategy. MCPS has not been able to maintain its replacement schedule due to fiscal constraints.

Buses account for 75 percent of the County and bi-County agency emissions. Older transit buses are a significant source of this pollution.

As stated earlier, MCG operates 17 pre-1991 and 49 pre-1994 transit buses. In late 2003 or early 2004, MCG will receive 33 new CNG buses and some of these buses will replace all of the remaining pre-1991 diesel transit buses. Under its regular replacement cycle, MCG also expects to budget for the replacement of all pre-1994 buses in the FY 2005-2006 budget. The pre-1994 buses would actually be replaced in 2006-2007 when the buses are delivered. The new CNG buses will produce six times less NOx, three times less VOC, and 56 times less PM per mile than the pre-1991 diesel buses they replace.

MCPS operates 112 pre-1991 school buses. MCPS' adopted replacement cycles for its buses reflect the replacement cycles established in state law (Maryland COMAR 13A02.07). The law requires MCPS to replace conventional buses every 12 years and other buses every 15 years.

State law also provides a procedure to request a waiver from these provisions. Since 2001, the State has granted MCPS a waiver to defer the replacement of 78 buses. MCPS staff recognize that these buses emit more pollutants than the newer buses in the fleet.[4] MCPS staff also expressed concerns that these buses do not have the upgraded safety equipment, such as brakes, roof hatches, child find buttons and strobe lights, which has been specified for more recent purchases. These older buses also have higher maintenance costs because State law requires an additional inspection.

E. AGENCY CHALLENGES

Agency staff face many challenges in managing the emissions of their respective vehicle fleets. Some of the challenges come from the ongoing task of managing fleet vehicles in general; others relate more specifically to monitoring and managing emissions.

Finding #E1: A fleet manager's job includes making sure that the buses are available, and meeting the needs of user departments at the lowest possible cost. Fleet managers have only limited authority to experiment with emerging or expensive technology within these constraints.

Many of the strategies to reduce vehicle emissions rely on expensive or emerging technologies. For example, although a hybrid electric car has significantly lower emissions than a conventional sedan, it costs approximately twice as much. Similarly,

[4]For example, a bus built in 1989 bus emits pollutants at twice the rate of a bus built in 2002.

technologies such as hybrid electric buses or clean diesel buses appear to be promising but are still under development.

Fleet managers operate in an environment where cost and performance matter. For example, WSSC staff report that their overriding mission is to operate the fleet efficiently enough to avoid a rate increase. MCPS staff state that their highest priority is to keep the school bus fleet in operation. MCG staff observed that, given the relatively small size of its transit fleet, compared to transit agencies like New York City or WMATA, it is not well positioned to test out technologies that are not proven in the marketplace.

Finding #E2: Resources necessary to maintain a same services budget or adopt vehicle replacement schedules are frequently diverted elsewhere to address more pressing priorities. Moreover, agencies are reluctant to pursue new initiatives to reduce emissions when funding for core services cannot be maintained.

As internal service units, fleet departments operate in an environment where resources are frequently diverted elsewhere to address more immediate needs. To compensate, staff target resources to their core fleet management services and defer or cut back on other services.

To keep pace with increasing cost pressures on student transportation, MCPS has requested waivers from the State to defer bus replacement, eliminated preventive maintenance for its heavy duty equipment, and rarely replaces any of its heavy or light duty vehicles. MCPS reports that the vehicles in its heavy duty fleet are, on average, 18 years old. MCPS transferred eight school buses to the supply, maintenance, pool, and transportation divisions instead of purchasing new trucks.

The impact of diverting funds frequently shows up in extended replacement schedules. MCG has not been able to fully fund its vehicle replacement fund for two years and is also having difficulty finding funds to retire its backlog of heavy equipment.

Finding #E3: Fleet departments struggle to achieve user acceptance of new technologies and increase customer awareness of the importance of air quality issues.

Many strategies to reduce vehicle emissions require the awareness and cooperation of the vehicle operator. For example, a flexibly fueled vehicle will only reduce emissions if the driver fuels the vehicle with ethanol instead of gasoline.

Fleet managers across the agencies voice a common theme that anytime they try a new technology, user acceptance and changing user behavior is a challenge. MCG, for example, must continue to remind operators to use ethanol in the flexibly fueled vehicles. Fleet managers also observe that when you try a new technology and fail, it is even harder to introduce a new idea.

Finding #E4. The agencies do not maintain vehicle emission inventories and the agencies' ability to provide the data necessary to calculate emission estimates varies. In some cases, the fleet inventory data needed to estimate emissions was unavailable or inaccurate.

The maxim that "what gets measured gets done" is especially applicable for reducing emissions. Calculating an emissions inventory for a vehicle fleet requires data about the mileage, vehicle type, weight, and fuel type for each individual vehicle in the fleet. Developing annual emissions estimates ideally requires compiling these data on a regular basis. The agencies' ability to provide the necessary data for this OLO study varied; specifically:

- WSSC was able to provide the data for each vehicle on an fiscal year basis. The agency maintains an automated data information system and an automated fueling system, which enabled staff to provide the annual mileage, vehicle type and fuel consumption for each vehicle.

- Montgomery College was able to provide vehicle type, weight, fuel type and fiscal year mileage for each vehicle, but was not able to provide annual fuel consumption data.

- M-NCPPC has an automated vehicle inventory system but does not have an automated fueling system. M-NCPPC was able to provide lifetime vehicle mileages and estimated fuel efficiency by vehicle class.

- MCG uses an automated vehicle inventory system and automated fueling system to manage the vehicles maintained by the County; MCG relies on a contractor for data related to its mini-bus fleet. MCG provided actual annual mileage and fuel consumption data for the vehicles it maintains; however, MCG reported problems with the completeness and accuracy of the data. The bus inventory and the heavy truck mileage data were especially problematic. MCG provided estimated data for the portion of the bus fleet maintained by the contractor.

- MCPS was able to provide the total fiscal year mileage and total fiscal year fuel consumption for the bus fleet. For the other fleets, MCPS was able to provide fiscal year mileage and fuel consumption by department.

F. THE AGENCIES' GASOLINE AND DIESEL POWERED OFF-ROAD EQUIPMENT

Finding #F1: Emission standards for non-road engines[5] did not exist before 1996 and remain less stringent than standards for on-road vehicles. EPA plans to propose new engine and diesel fuel standards to further reduce pollutants emitted by non-road engines.

Nationwide data shows that diesel engines (especially heavy duty diesel engines in bulldozers, backhoes, and loaders) account for about 44 percent of diesel particulate matter emissions and about 12 percent of nitrogen oxide emissions from mobile sources. The County's Department of Environmental Protection estimates that non-road engines (e.g., lawn and garden equipment, construction equipment) emit approximately 20 percent of the total ozone forming pollutants in the County.

In 1994, EPA developed three sets of standards to regulate emissions from non-road engines:

- Tier 1 standards primarily regulate lawn and garden equipment (less than 50 horsepower) and apply from 1997 to 2005.

- More stringent Tier 2 standards will be phased in from 2003 to 2006. The Tier 2 standards reduce emissions from engines over the size of 50 horsepower.

- Even tougher Tier 3 standards apply to engines between 50 and 750 horsepower and take effect between 2006 and 2008. The Tier 3 standards should lead to the production of new engines with advanced emission control technologies (e.g., catalytic converters).

EPA plans to introduce new Tier 4 emissions standards to further reduce emissions from non-road engines in 2008. EPA's proposal reduces the sulfur content in "off-road" diesel fuel to match current on-highway diesel standards. The proposal calls for the use of low-sulfur diesel (500 ppm) starting in 2007 and ultra-low sulfur diesel (15 ppm) in 2010.

Finding #F2: The five agencies collectively own 4,469 pieces of non-road engine equipment. 83 percent (3,691 pieces) of this inventory is gas operated and 17 percent (778 pieces) is diesel fueled equipment.

- M-NCPPC and MCPS together own over two-thirds of the total non-road engine inventory. M-NCPPC owns 1,647 pieces or 37 percent of the total inventory; MCPS owns slightly over 1,500 pieces of equipment; or 34 percent of the total.

[5] The term "non-road" refers to off-road equipment fueled by diesel and gasoline. Examples include (but are not limited to) lawnmowers, chainsaws, boat motors, tractors, generators, and bull dozers.

- WSSC's inventory contains a significant number of off-road pieces of equipment. WSSC's 960 pieces account for 21 percent of the total inventory.

- Two agencies split the remaining 8 percent of the non-road inventory; MCG maintains 227 pieces and MC maintains 128 pieces.

- Except for WSSC, lawn and garden equipment represents the largest category of each agency's non-road engine inventory. Lawn mowers, edgers, trimmers, chainsaws, sod cutters, etc., account for:

    - 97 percent of MCPS' inventory;
    - 73 percent of MC's inventory;
    - 65 percent of M-NCPPC's inventory; and
    - 41 percent of the County Government's inventory.

Finding #F3: Heavy duty diesels and pre-1997 lawn and garden equipment contribute significantly to urban air pollution. A typical pre-1997 lawn mower emits the same amount of ozone forming pollutants in an hour as a new car emits while driving 340 miles.

- The five agencies combined maintain 293 heavy-duty diesels e.g., loaders, bulldozers, excavators, rollers, tractors, and graders. WSSC maintains the greatest number of diesel engines including 51 backhoes, 19 loaders, and two bulldozers.

  These diesel engines utilize low sulfur fuel, but are not equipped with emission control devices. However, most of the diesel engines receive adequate preventive maintenance and corrective maintenance, which helps engine performance.

- 92 percent of WSSC's lawn and garden equipment and nearly 60 percent of the Montgomery County Government's lawn and garden equipment dates pre-1997. Fleet staff from the other three agencies estimate that up to three-quarters of their lawn and garden inventory is older than six years.

VIII. Recommendations

The vehicles in the five agencies' fleets together produce approximately 738 tons of nitrogen oxides, 211 tons of volatile organic compounds, and 24 tons of particulate matter each year. The major sources of these pollutants are school buses, transit buses and heavy trucks. Older buses and trucks are especially problematic; pre-1994 buses and trucks produce 23 percent of all emissions.

Now is a promising time to figure out how to reduce vehicle fleet emissions. Some strategies and vehicle technologies exist to reduce these emissions today. The availability of ultra low sulfur diesel fuel in the Washington D.C. area and new bus technologies should make these reductions even more achievable over the next five to seven years.

OLO recommends that the Council engage the agencies in a two-step process to develop an inter-agency action plan. The plan would outline priority strategies and endorse specific projects to reduce vehicle fleet emissions. Based upon research into promising practices, OLO has identified 11 potential strategies to reduce the emissions of the agency fleets. These strategies are presented in two separate exhibits on the following pages. **The strategies are not mutually exclusive and are not listed in priority order because the cost-effectiveness of each strategy still needs to be determined.**

Exhibit 46 (page 81) lists each strategy with a relative cost and emission savings estimate; Exhibit 47 (page 82) provides a brief description of each strategy.

- Strategies listed in Section A apply to vehicles owned by all agencies;
- Strategies listed in Section B are additional strategies applicable only to the MCPS school bus fleet; and
- Strategies listed in Section C are additional strategies applicable only to the County Government's transit fleet.

OLO recommends the Council use the list of strategies to encourage the agencies to think creatively about feasible, cost effective options to reduce vehicle emissions.

The strategies differ in their costs, emission savings and pollutant(s) targeted for reduction. The strategies achieve different policy objectives, depending on the pollutant the strategy addresses. All strategies will improve public health, and the school bus strategies in particular, will reduce children's exposure to pollutants. Strategies that target nitrogen oxide and hydrocarbons will help reduce ozone. Potentially, these strategies could be counted toward efforts to address the region's ozone nonattainment status; however, calculating the specific impact of this will require additional computer modeling work.

OLO recommends the following two-step process to develop an action plan of cost effective strategies.

Step 1: OLO recommends the Council transmit the list of potential strategies to the five agencies with a request for a response within a set time period.

The Council should transmit the list of potential strategies to the five agencies and formally request that each agency develop recommendations for feasible, cost effective priority projects to reduce fleet vehicle emissions. The Council's request should specifically ask each agency to provide an estimated cost, implementation schedule, and emission savings estimate for each project the agency recommends. The Council should set a deadline for the agencies' responses, i.e., 90-120 days.

The Council's request should also ask the agencies to speak to the overriding public policy objectives of their respective recommendations. In particular, each agency should be asked to weigh in on whether the Council should be guided by public health concerns, ozone nonattainment issues, or a combination of the two as it sets priorities for the action plan to reduce fleet vehicle emissions. The Council should ask the agencies to describe how the agencies' recommendations would address each of these concerns and comment on the merits of pursuing the additional work that would be needed to incorporate these projects into the regional solution to bring the area into compliance under the Clean Air Act.

Step 2: OLO recommends the Council review the agencies' responses with the goal of adopting an inter-agency action plan that outlines priority strategies and endorses specific projects to reduce vehicle fleet emissions.

The Council's inter-agency action plan should identify funding, a project implementation timeline, and an estimate of the anticipated emission savings. The Council will also need to decide whether and how to integrate its action plan to reduce emissions with the regional efforts currently underway to address the ozone nonattainment issue.

EXHIBIT 46: EMISSION REDUCTION STRATEGIES

Strategy #	Strategy Description	Relative Cost	Relative Emission Savings	Pollutants Addressed
A. STRATEGIES FOR ALL AGENCIES				
A.1	Reduce fleet size, vehicle size and vehicles miles traveled.	Low	Unknown	All
A.2	Establish a campaign to limit idling.	Low	Unknown	All
A.3	Replace pre-1994 heavy trucks.	High	High	PM and NO_X
A.4	Convert to ultra low sulfur diesel fuel in 2006 or earlier.	Low	Moderate	PM[1]
A.5	Replace pre-1997 lawn and garden equipment.	Low	Moderate	All
A.6	Retrofit heavy duty diesel off road equipment.	Moderate to High	Moderate to High	VOC and PM
B. ADDITIONAL STRATEGIES FOR SCHOOL BUSES				
B.1	Replace pre-1991 school buses.	High	High	All
B.2	Discontinue the practice of requesting waivers & fully fund MCPS bus replacements for the foreseeable future.	High	Moderate	All
B.3	Pursue EPA funds to retrofit school buses.	Low	Moderate	PM
C. ADDITIONAL STRATEGIES FOR TRANSIT BUSES				
C.1	Pursue EPA funds to retrofit additional diesel transit buses.	Low	Moderate to High	VOC and PM[2]
C.2	Replace older buses with clean bus technology.	Unknown	Unknown	All

Source: OLO, May 2003

[1] Diesel vehicles built in MY 2007 and beyond will reduce NO_X emissions using ULSD fuel only because manufacturers are expected to modify the engine design.

[2] In the future, retrofit devices that are currently under development, such as exhaust gas recirculation (EGR), selective catalytic reduction (SCR), and lean NO_X catalysts, will also reduce NO_X emissions.

Exhibit 47: Emission Reduction Strategy Descriptions

A. STRATEGIES FOR ALL AGENCIES	
A.1	**Reduce fleet size, vehicle size and vehicles miles traveled.** This is a low cost management strategy that could save money and reduce pollution. An agency could conduct a comprehensive review of user needs or could target a specific program or function for review. For example, this strategy could look at route planning for transit and/or school buses. At its most effective, this strategy could look at broadly re-defining service delivery to reduce vehicle use. The Council's recent action to implement trash free parks will reduce vehicle miles traveled and emissions as well.
A.2	**Establish a campaign to limit idling**. This is a low cost management strategy that could save money and reduce pollution. An anti-idling campaign would increase awareness of the cost and emission impacts of idling. Most agencies report that they have idling policies which are informally enforced.
A.3	**Replace pre-1994 heavy trucks**. This is a high cost replacement strategy that could significantly reduce nitrogen oxide pollution and save money spent on preventive maintenance. The agencies 493 pre-1994 heavy trucks emitted eight percent of the fleet's total pollutants. This is a significant finding, considering that the pre-1994 heavy trucks traveled only four percent of the fleet's total miles. Replacing a 1993 heavy truck with a 2003 heavy truck would achieve a 63 percent reduction in PM emissions, a 55 percent reduction in NO_X emissions and a 62 percent reduction in VOC emissions. Replacing a 1989 heavy truck would achieve even greater benefits, i.e., a 84 percent reduction in PM, a 80 percent reduction in NO_X, and a 63 percent reduction in VOC.
A.4	**Convert to ultra low sulfur diesel fuel (ULSD) in 2006 or earlier.** This is a future regulatory requirement that will reduce particulate matter pollution. Based on testing and EPA pilot studies in Washington, D.C. and New York City, the use of ultra low sulfur diesel fuel (ULSD) by itself reduces particulate matter emissions 25 to 30 percent. In 2006, EPA regulations will take effect requiring the use of ULSD fuel, which has a sulfur content of 15 parts per million, compared to a sulfur content of 350-500 ppm in diesel fuel used currently.
A.5	**Replace pre-1997 lawn and garden equipment.** This low cost strategy could reduce nitrogen oxide, volatile organic compounds and particulate matter pollution through natural attrition. Agency staff report most lawn and garden equipment has a useful life of five to seven years; however OLO found 92% of WSSC and nearly 60% of the County Government's lawn and garden equipment pre-dates 1997. The other three agencies believe that up to three-quarters of their lawn and garden inventory is older than six years.
A.6	**Retrofit heavy duty diesel off-road equipment with particulate filters or diesel oxidation catalysts.** This is a moderate to high cost strategy that can reduce particulate matter and volatile organic compound pollution. Diesel particulate filters cost $10,000 to $13,000 and can reduce particulate matter and hydrocarbon pollution by 50 to 90 percent. The technology can be applied to both large and small diesel engines. Diesel oxidation catalysts cost $2,500 and provide modest PM emission reductions compared with the filters. This strategy requires the use of ultra low sulfur diesel fuel.

EXHIBIT 47 (CONTINUED):

B. ADDITIONAL STRATEGIES FOR SCHOOL BUSES	
B.1	**Replace pre-1991 school buses.** This is a high cost replacement strategy that could significantly reduce nitrogen oxide, volatile organic compound, and particulate matter pollution. Pre-1991 school buses pollute at significantly higher rates than buses built more recently. In FY 03, MCPS operated 112 pre-1991 school buses. The approved FY 04 budget provides funding to replace 12 of these buses, which will leave 100 still in operation. 43 of these buses are past due for replacement and 57 are scheduled to be replaced in 2006. Based on emission factors, replacing a pre-1991 bus would achieve an 80 percent reduction in particulate matter emissions, a 60 to 75 percent reduction in nitrogen oxide emissions and a 57 percent reduction in volatile organic compounds.
B.2	**Discontinue the practice of requesting waivers and fully fund MCPS bus replacements for the foreseeable future.** This is a high cost replacement strategy that could moderately reduce nitrogen oxide, volatile organic compound and particulate matter pollution. Over the next four years MCPS is scheduled to replace its remaining pre-1991 buses and some of its pre-94 buses. Recently, budget constraints have forced MCPS to request waivers to defer bus replacement so that it could purchase buses to support new growth.
B.3	**Pursue EPA funds to retrofit school buses.** This spring, the EPA announced funding for a Clean School Bus initiative. The goal of the initiative is to reduce children's exposure to diesel exhaust and the amount of air pollution created by school buses. EPA has identified grant funds that school districts can use to retrofit buses to reduce these harmful pollutants. EPA expects to publish the request for proposal in June 2003 and award five to ten grants of $500,000 to $1 million each.

Exhibit 47 (Continued):

C. ADDITIONAL STRATEGIES FOR TRANSIT BUSES	
C.1	**Pursue EPA funds to retrofit additional diesel transit buses.** EPA's Voluntary Diesel Retrofit Program funds pilot projects that reduce emissions from diesel engines. EPA periodically seeks proposals from transport fleet owners to retrofit existing diesel engines with certified pollution control devices. Commonly used devices such as diesel particulate traps and diesel oxidation catalysts can reduce PM and VOC pollution by 50 to 90 percent. The program has assisted other counties and transportation authorities retrofit diesel transit buses, including New York City Transit and King County.
C.2	**Replace older buses with clean bus technology.** This is a high cost strategy that can reduce nitrogen oxide, volatile organic compound and particulate matter pollution. It works because buses built before 1991 emit pollutants at significantly higher rates and buses built before 1994 or 1998 emit pollutants at moderately higher rates than buses built today. More importantly, the buses built in the next three to six years are expected to be even cleaner. The emission savings depend on the model year and fuel type of the existing bus and the model year and fuel type of the replacement bus. For example, MCG currently has 33 CNG buses on order and anticipates all of these will replace all remaining pre-1991 diesel buses. Based on the differences in emissions standards, the new CNG buses will produce six times less NOx, three times less VOC, and 56 times less particulate matter per mile than the pre-1991 diesel buses they replace. Model year 2004 buses and the buses that will be built in the next three to five years create excellent opportunities to reduce emissions through replacement, regardless of the technology or fuel type. Diesel buses built today have nitrogen oxide emissions that are less than half the rates of a pre-1997 diesel bus. In 2007, new EPA emission standards for diesel buses are scheduled to take effect that would reduce the emissions of nitrogen oxide and volatile organic compounds to levels below those of a model year (MY) 2004 CNG bus. The 2010 standards for diesel buses would reduce nitrogen oxide and particulate matter even further. Over the same period, the emission standards for CNG buses are expected to improve to keep pace with clean diesel buses.

IX. Agency Comments

The Office of Legislative Oversight circulated a final draft of this report to the five County and bi-County agencies and the Environmental Air Quality Committee. The final report incorporates all of the technical corrections provided by the agencies.

Written comments from the Chief Administrative Officer, the General Manager of the Washington Suburban Sanitary Commission, and the Environmental Air Quality Committee are included in their entirety beginning on the following page.

OLO greatly appreciates the time taken by everyone who reviewed the draft report and looks forward to discussing the issues raised in this study.

OFFICES OF THE COUNTY EXECUTIVE

Douglas M. Duncan
County Executive

Bruce Romer
Chief Administrative Officer

June 19, 2003

TO: Sue Richards, Program Evaluator
Scott Brown, Legislative Analyst
Ben Stutz, Research Assistant
Office of Legislative Oversight

FROM: Bruce Romer
Chief Administrative Officer

SUBJECT: Office of Legislative Oversight DRAFT Report, 2003-4,
An Emissions Analysis of the County and Bi-County Agency Fleets

Thank you for the opportunity to review the draft of the above referenced report. In general, we believe that this report accurately reflects the strategies for controlling emissions from the agencies' vehicle and off-road fleets. Please consider the attached general comments as you prepare the final version of Office of Legislative Oversight DRAFT Report, 2003-4. My staff will be in contact with you regarding some of the more technical comments.

Thank you again for your invitation to comment on the draft report.

BR:rsd

cc: Al Genetti, DPWT

Attachment

101 Monroe Street • Rockville, Maryland 20850
240/777-2500, TTY 240/777-2544, FAX 240/777-2517
www.co.mo.md.us

DPWT General Comments and Observations Regarding Office of Legislative Oversight Report 2003-4, "An Emissions Analysis of the County and Bi-County Agency Fleets"

General Comments:

1. The report gives an excellent summary of the need for cleaner air and the regulatory efforts to control air quality. The summary would be even more useful to the elected officials if it provided a timeline of regulatory mandates that will have an effect on emissions by the agencies' fleets. In this manner, recommendations that could be implemented today at a cost to the County can be checked against the timing of future federal mandates that may deny the wisdom of the expenditure.
2. The report should emphasize more the fact that air quality is a much larger regional issue. It would be useful if the report estimated the regional effect if the County implemented ***all*** OLO recommendations, at whatever cost. This would put our efforts into better perspective at a time of budgetary constraints.
3. The report should put this issue into context in our region. It should include a graph showing the levels of pollutants from 1990 thru 2030. COG has developed such graph indicating that emissions by 2030 will be about 12 percent of those in 1990. This is an expected 88 percent reduction. Despite the gloomy news, our air today is much cleaner than 13 years ago, and it will be even cleaner in 2007 and beyond. Independent of whatever additional actions are taken by the County. This is due mostly to federal regulatory standards for diesel engines, SUV regulations, off-road vehicles and controls on other sources of air pollution.
4. The report should further emphasize the relationship between congestion/low speeds and emissions. It should show charts indicating emission rates as a function of vehicular travel speeds. Improving speeds in our transportation network will result in emission reductions for our fleets, but even more importantly, for every motorist in our transportation system.
5. In many sections of the report emissions are treated as a single unit. We do not believe this should be the case. There are very different emission rates for NOx and VOC and the cost effectiveness of reduction measures vary considerably for each. The report should emphasize more which of the two is the real problem in the region, so that if the Council adds additional funding for emission reductions we put the money where the real problem is.
6. Off-road equipment constitutes about 23 percent of the VOC and about 18 percent of the NOx emissions, according to Exhibit 34, page 51. But there is nowhere in the report a detailed explanation of the different components of these emissions. If the operation of a chain saw for one hour is the equivalent of driving a vehicle for 200 miles (Ex. 33, pg. 50), shouldn't we explore more the implementation of the inexpensive but cost effective measures to replace the chainsaw first? More detail is needed in this section to explore this issue.

7. Many of the recommendations involve the investment of significant funds and additional technical staff. Current organizations are not staffed to perform this type of monitoring. This must be recognized during the discussion of the report and the implementation of the recommendations.
8. The report should emphasize that the Washington DC metropolitan region is expected to be in compliance with air quality standards in the future. The problem that we are dealing with now is for 2005. Timeliness of the investment in implementing recommendations must be recognized. The wisdom and costs associated with implementation of some of the recommendations beyond, say 2007, must be weighted against expenditures in other County programs.

WASHINGTON SUBURBAN
SANITARY COMMISSION

14501 Sweitzer Lane • Laurel, Maryland 20707-5902

June 12, 2003

Ms. Sue Richards, Program Evaluator
Office of Legislative Oversight
100 Maryland Avenue,
Rockville, Maryland 20850

Re: Review of Draft Office of Legislative Oversight Report 2003-4: An Emissions Analysis of the County and Bi-County Agency Fleets

Dear Ms. Richards:

Thank you for the opportunity to review the draft Fleet Emissions Analysis Report prior to its submission to the Montgomery County Council. The report is quite comprehensive and well written. Our comments and suggestions on the text are as follows:

- Revise Exhibit 40, page 61 for WSSC to indicate: two excavators, four mowers, and eight forklifts giving a revised total diesel equipment fleet of 267 units. All other fleet listings on that exhibit are correct.

- Revise Finding #A6 to delete "WSSC owns seven CNG sedans".

We will have some comments on the recommendations when your final report is released, but in general find most of them workable. Should you have any follow-up questions to our suggested revisions, please feel free to directly contact Allen W. Cartwright, Jr., Chief of Mission Support, or William R. Banwarth, Fleet Services Group Leader. If we can be of further assistance, please advise.

Sincerely,

John R. Griffin
General Manager

cc: Deputy General Manager
Chief of Mission Support
Fleet Services Group Leader
Scott Brown, Legislative Analyst
Ben Stutz, Research Assistant

ENERGY/AIR QUALITY ADVISORY COMMITTEE

June 17, 2003

Sue Richards
Office of Legislative Oversight
100 Maryland Avenue, Suite 509
Rockville, MD 20850

Dear Ms. Richards:

The Energy and Air Quality Committee (EAQAC) welcomes the opportunity to comment on the draft report "An Emissions Analysis of the County and Bi-County Agency Fleets" by the Office of Legislative Oversight (OLO). The following comments relate to policy issues (detailed technical comments were sent separately).

This report is timely because it identifies transportation emission reduction strategies for agency fleets, and recommends a Council and agency planning process to reduce emissions at a time when the Washington region has been reclassified as a severe nonattainment area for ozone. We recognize that the County should lead by example and the scope of this report wisely includes actions that agencies can take in their operations. However, the report does not include actions the County Council can take affecting the public's transportation choices which, coupled with federal emissions regulations, will ultimately address the Clean Air Act attainment and public health issues. A more useful study would focus not only on agency actions, but on regional strategies that address the ozone nonattainment issue, coupled with a detailed cost/benefit analysis of options.

While emissions inventories are developed and a discussion follows on strategies to reduce emissions, the objective is not clearly stated. Is it to address ozone nonattainment? If so, NOx and volatile organic compounds (VOCs) are of interest (their ratio is important). Diesels produce high levels of NOx, but very low levels of VOCs, while gasoline and natural gas engines (and fueling systems) emit high levels of VOCs but low levels of NOx. The report should recognize that balancing these opposing emissions signatures in the fleets is important.

Other pollutants may also be of interest to the Council, but may result in totally different strategies than those taken to reduce ozone. For example, carbon monoxide is of interest in closed buildings and in urban settings, wheras particulate matter is of concern in urban settings and perhaps on a regional scale. Moreover, with a few small additions, the report could help advance concurrent work by the County to address climate change. The report notes, in the context of emissions inventories, that the County is part of the Cities for Climate Protection campaign, under which it has

Department of Environmental Protection
255 Rockville Pike, Suite 120 • Rockville, 1 20850-2589 • 240/777-7770, FAX 240/777-7752

completed an inventory of greenhouse gas emissions and is moving ahead to adopt target reductions. There are a few instances where the report identifies the potential ancillary greenhouse emissions reduction benefits from potential measures, and example of which is diesel idling provisions. Broadening the analysis to highlight the CO_2 emissions reduction potential, for all or at least a majority of the measures, could help prioritize those that could simultaneously achieve air quality and climate change goals.

While the study touches on costs and benefits of technology options, a more detailed analysis is recommended. For example, OLO concludes that older buses should be replaced with new "clean" technology, but detailed information is lacking on which technology/fuel is cleaner, and on the cost and availability of each technology/fuel. A detailed cost/benefit analysis should be performed at the agency level for each technology/fuel option (including retrofit options). For example, the optimal choice may be to wait until the new diesel emission standards are in place (2007) before purchasing new diesel vehicles, and to retrofit existing diesels with new technology. The scope of the cost/benefit analysis should include agency fleets as well as overall regional transportation options.

We hope you find these comments useful, and we thank you for the recent presentation before the Committee.

Sincerely,

Jeff Komarow, Chair
Energy and Air Quality Advisory Committee

Frank Stodolsky
Transportation Subcommittee

APPENDICES

DETAILS OF MONTGOMERY COUNTY GOVERNMENT ON-ROAD CAR AND TRUCK FLEET (EXCLUDING TRANSIT BUSES)

In FY 02, MCG maintained a fleet of 2,534[1] vehicles that traveled 27.9 million miles, used 2.2 million gallons of fuel, achieved fuel efficiency of 12.7 miles per gallon, and emitted 119 tons of pollutants.

The characteristics of the MCG fleet are summarized below.

EXHIBIT 48: MCG VEHICLE FLEET COMPOSITION AND POLLUTANTS – FY 02

Vehicle Class	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel (millions)	Miles Per Gallon	Total Emissions (Tons)
Passenger Cars	1,506	20.1	N/A	N/A	16.47
Light Trucks	389	4.6	N/A	N/A	7.82
Heavy Trucks	589	3.2	N/A	N/A	94.59
Total	**2,484**	**27.9**	**2.2**	**12.7**	**118.88**

Exhibit 49 provides detailed information about the amount of pollutants by vehicle class.

EXHIBIT 49: MCG VEHICLE FLEET – POLLUTANTS EMITTED FY 02

Sub Fleet	NO_x (Tons)	VOC (Tons)	PM (Tons)	NO_x (%)	VOC (%)	PM (%)
Passenger Cars	9.05	5.58	1.84	10%	21%	37%
Light Trucks	5.03	2.23	0.56	6%	9%	11%
Heavy Trucks	73.86	18.17	2.56	84%	70%	52%
Total	**87.94**	**25.98**	**4.96**	**100%**	**100%**	**100%**

In addition to the emission information presented in the body of the report, OLO calculated several other measurements to analyze the emissions of each agency's fleet. The following pages of the appendix present data for the MCG fleet. The measures include:

- Emission rates per mile by vehicle class;
- Average amounts of pollutants by vehicle class;
- The pollutants of pre-1994 vehicles as a percent of total fleet pollutants; and
- The relationship between a specific pollutant and vehicle miles traveled by vehicle class.

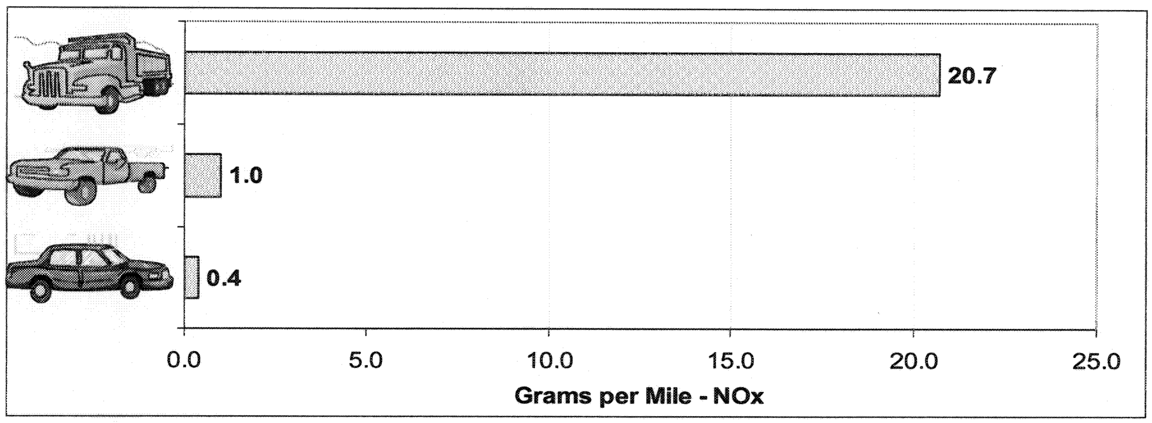
[1] Total vehicle miles traveled and tons of emissions based on 2,484 vehicles.

1. Emission Rates per Mile

The rate at which a vehicle produces NO_x, VOC, and PM depends on the class of vehicle and the vehicle age. Exhibits 50, 51, and 52 show the average rate per mile of the pollutants produced for a passenger car, a light truck, and a heavy truck in the MCG fleet.

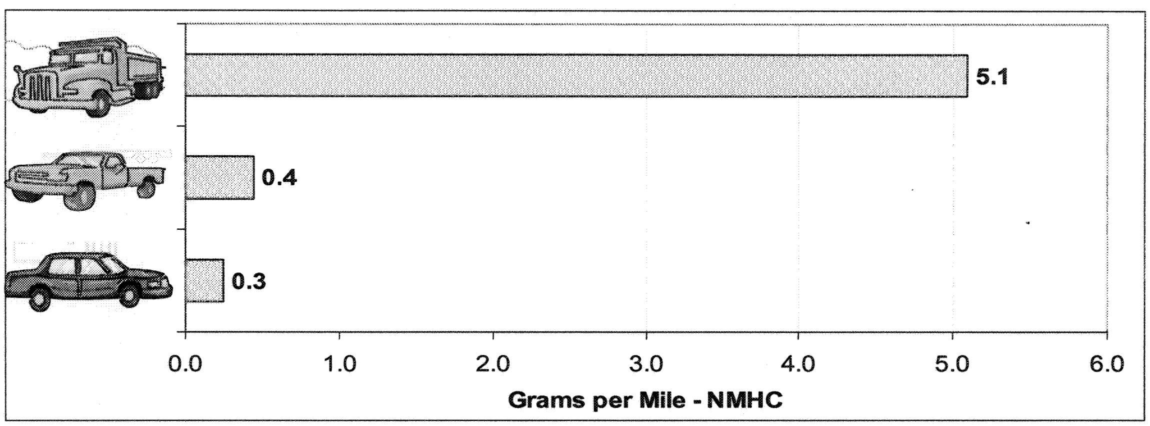
The exhibits show heavy trucks emit all pollutants at significantly greater rates that passenger cars or light trucks.

EXHIBIT 50: GRAMS OF NO_X EMITTED PER MILE IN FY 02



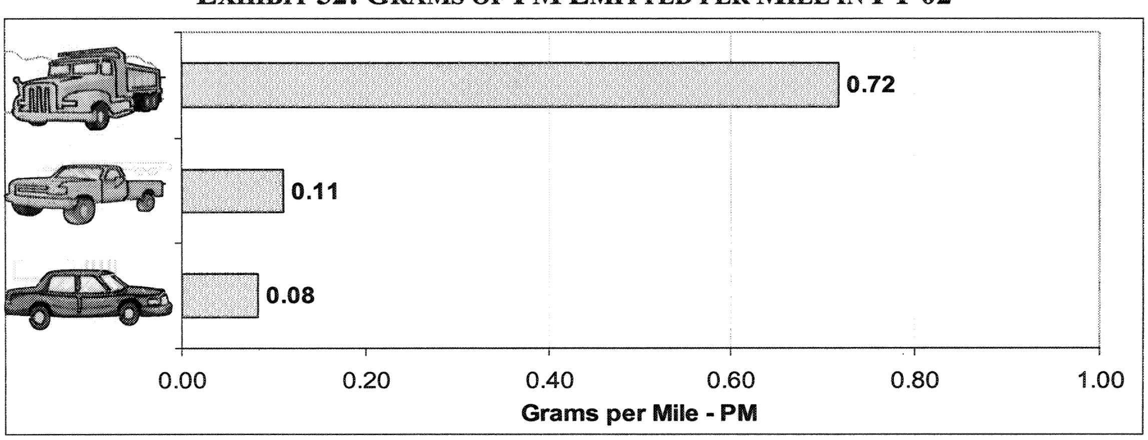
Source: OLO April, 2003

EXHIBIT 51: GRAMS OF VOC EMITTED PER MILE IN FY 02



Source: OLO April, 2003

EXHIBIT 52: GRAMS OF PM EMITTED PER MILE IN FY 02



Source: OLO April, 2003

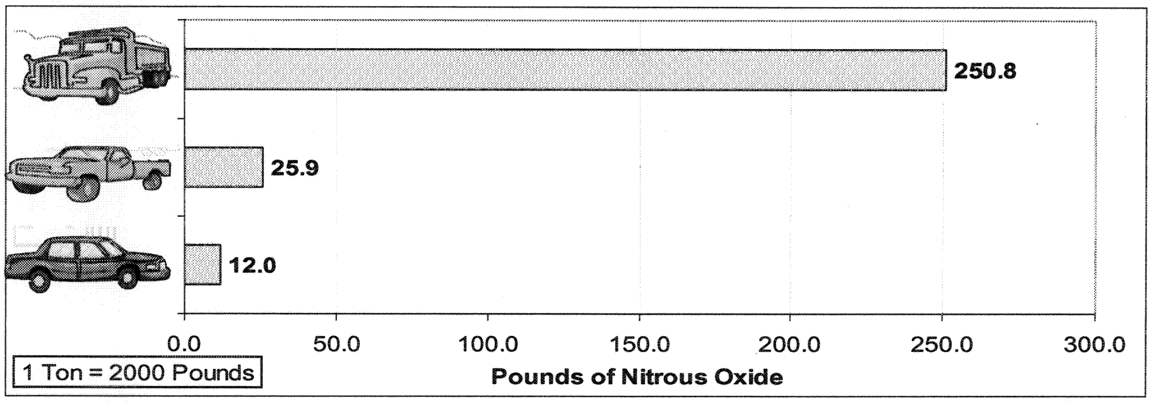
2. Emissions of NO_x, VOC, and PM per Vehicle

Exhibits 53, 54, and 55 present the emissions of NO_x, VOC, and PM for a passenger car, a light truck, and a heavy truck in the MCG fleet taking into account the vehicle miles traveled in FY 02. These graphs show:

- On average, a heavy truck emits nearly 10 times the amount of NO_x and five and a half times the amount of VOC than a light truck,

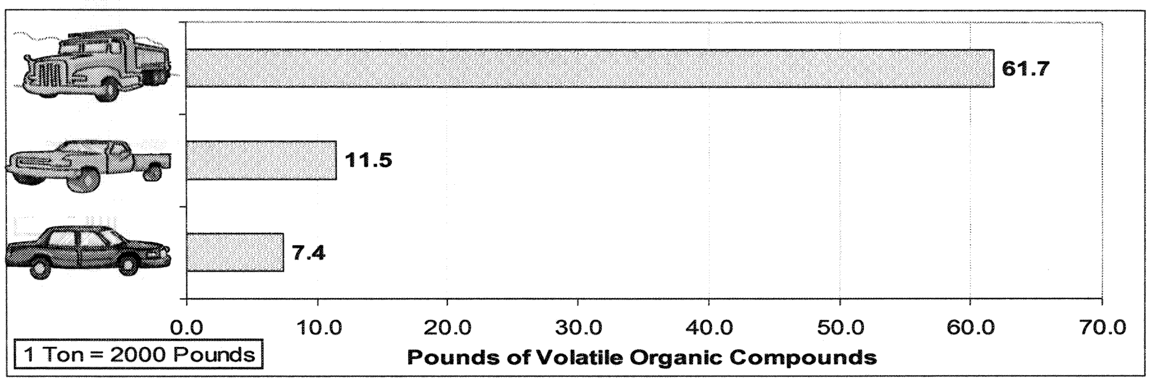
- On average, a heavy truck emits 3 times the amount of PM than a light truck and 4 times the amount of PM than a passenger car.

EXHIBIT 53: AVERAGE POUNDS OF NO_X EMITTED PER VEHICLE IN EACH CLASS - FY 02



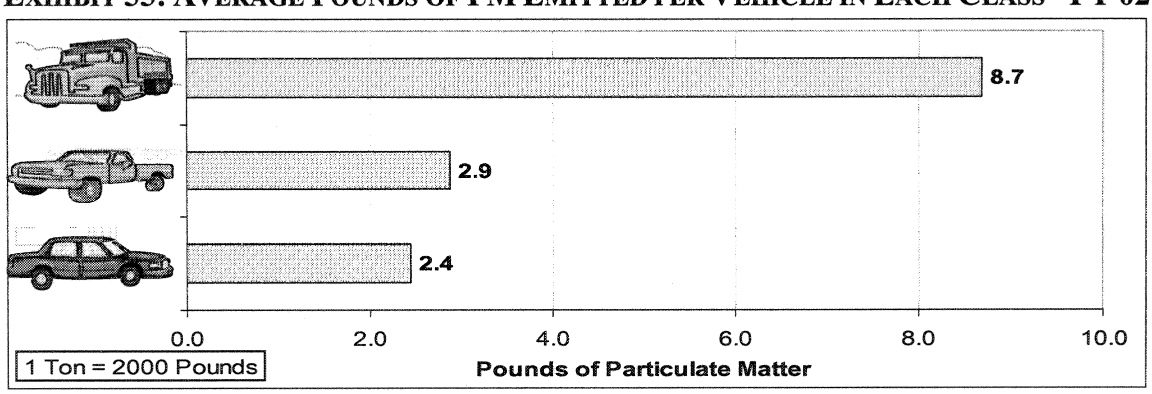
Source: OLO April, 2003

EXHIBIT 54: AVERAGE POUNDS OF VOC EMITTED PER VEHICLE IN EACH CLASS - FY 02



Source: OLO April, 2003

EXHIBIT 55: AVERAGE POUNDS OF PM EMITTED PER VEHICLE IN EACH CLASS - FY 02

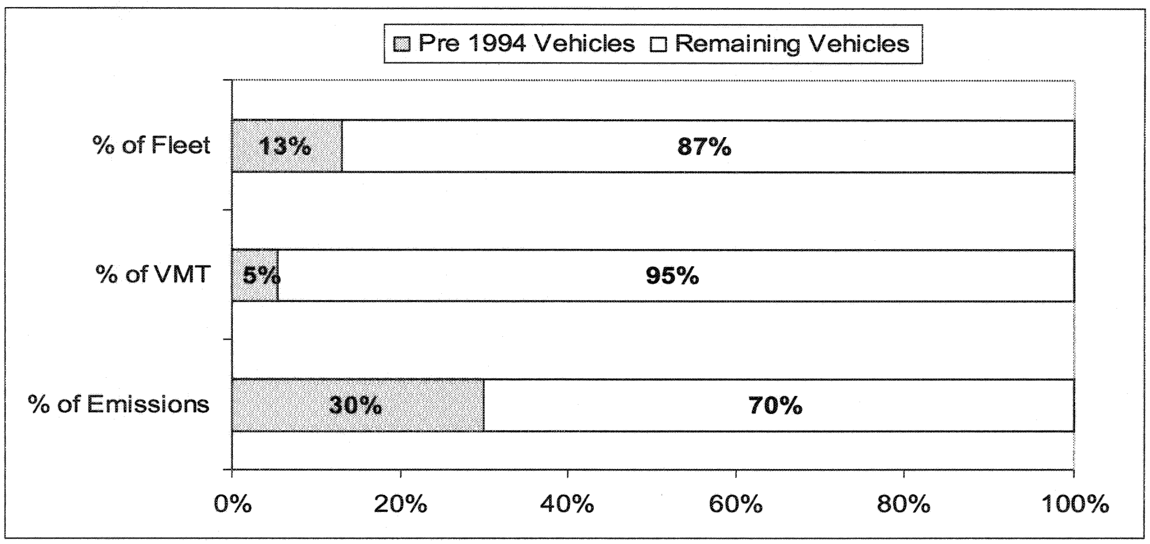


Source: OLO April, 2003

3. Vehicle Age and Emission Levels

OLO calculated the amount of pollution emitted by MCG's 329 pre-1994 vehicles that account for 13% of the total fleet and 5% of the total mileage. OLO found these vehicles account for 30% of the fleet's total emissions.

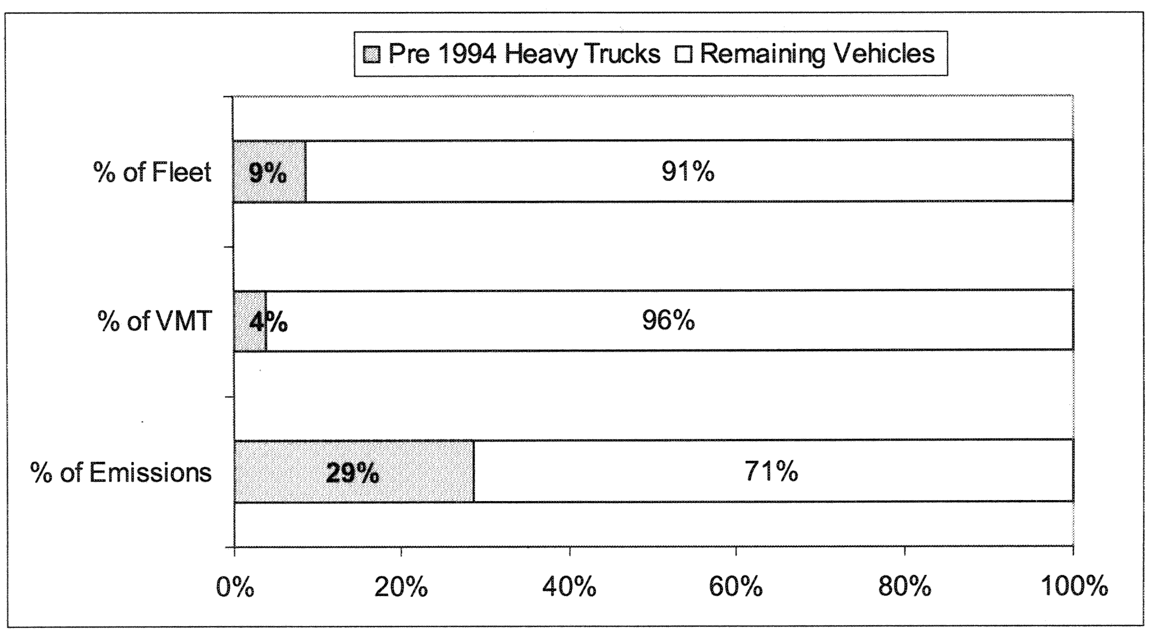
EXHIBIT 56: IMPACT OF PRE-1994 VEHICLES ON FLEET EMISSIONS IN FY 02



Source: OLO April, 2003

OLO also calculated the amount of pollution emitted by MCG's pre-1994 heavy trucks. Exhibit 57 shows these 217 older trucks account for 9% of the total fleet, 4% of the total mileage, and 29% of the total emissions. OLO believes that the pre-1994 heavy truck emissions are significant given the relatively small number of miles traveled by these vehicles.

EXHIBIT 57: IMPACT OF PRE-1994 HEAVY TRUCKS ON FLEET EMISSIONS IN FY 02

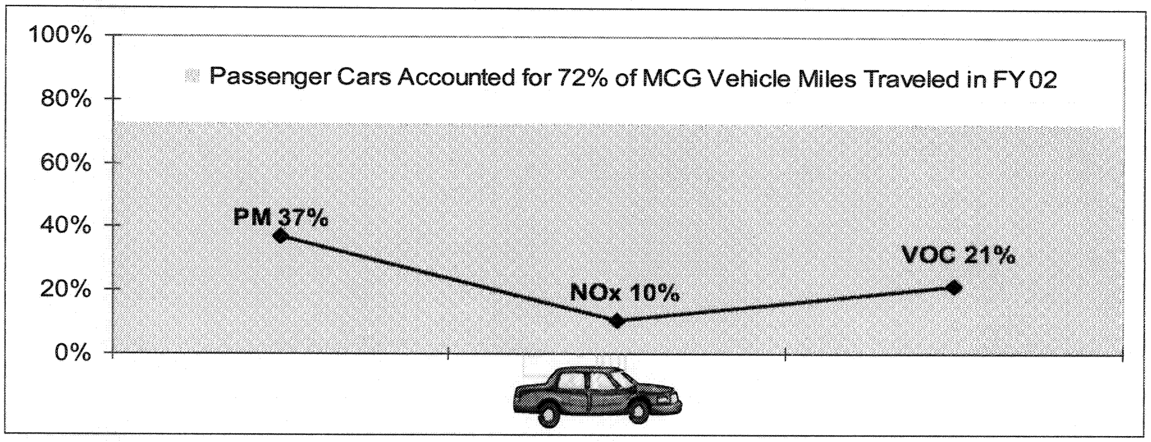


Source: OLO April, 2003

4. Emission Levels and Vehicle Miles Traveled by Vehicle Class.

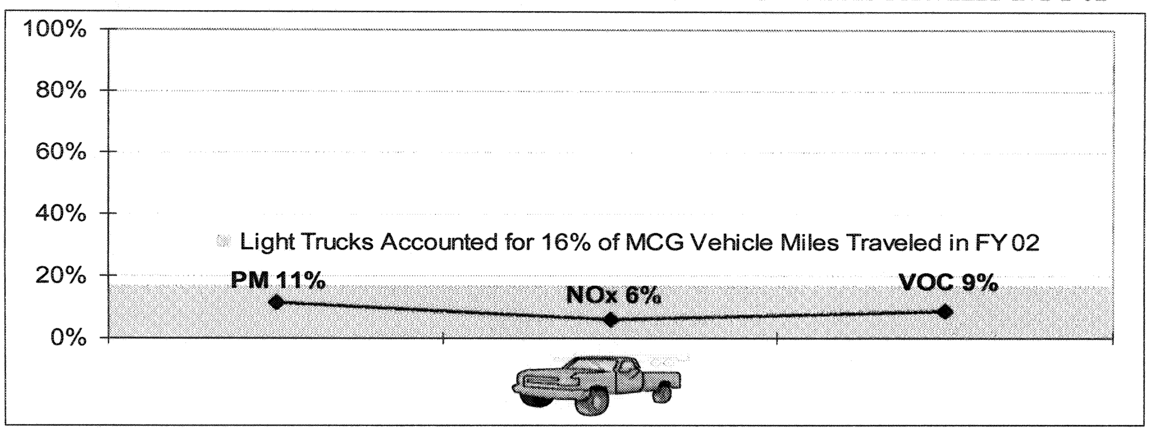
OLO examines the relationship between specific pollutants and vehicle miles traveled for each vehicle class. OLO found passenger cars and light trucks emit a disproportionately lower share of pollutants than heavy trucks. These results are summarized in Exhibits 58, 59, and 60 below.

EXHIBIT 58: PASSENGER CARS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



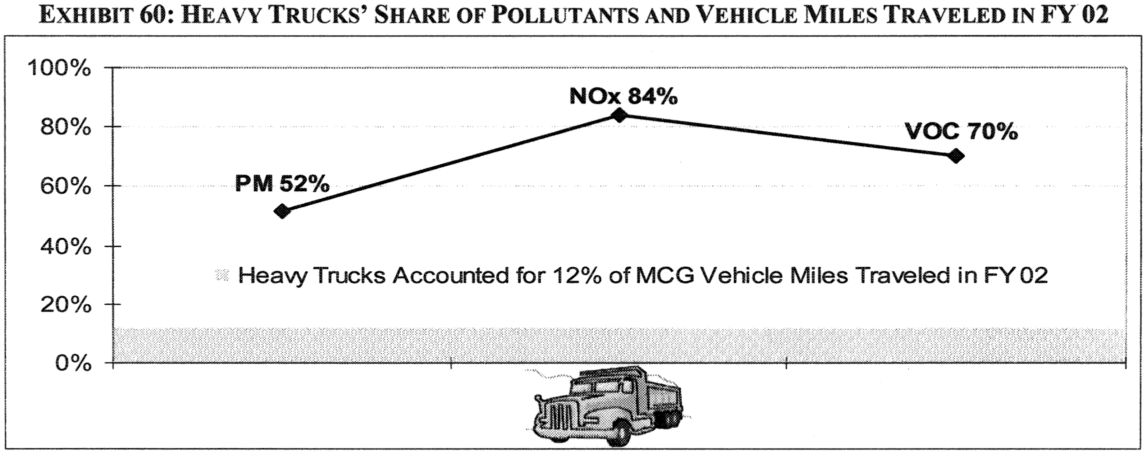
Source: OLO April, 2003

EXHIBIT 59: LIGHT TRUCKS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



Source: OLO April, 2003

EXHIBIT 60: HEAVY TRUCKS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



Source: OLO April, 2003

Details of Montgomery County Public Schools (MCPS) On-Road Car and Truck Fleet (Excludes School Buses)

In FY 02, MCPS maintained a fleet of 564 vehicles that traveled 3.4 million miles, used 389,000 gallons of fuel, achieved fuel efficiency of 8.7 miles per gallon, and emitted 45 tons of pollutants.

The characteristics of the MCPS fleet are summarized below.

Exhibit 61: MCPS Vehicle Fleet Composition and Pollutants – FY 02

Vehicle Class	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel	Miles Per Gallon	Total Emissions (Tons)
Passenger Cars	100	0.8	N/A	N/A	1.55
Light Trucks	243	2.2	N/A	N/A	3.45
Heavy Trucks	221	1.4	N/A	N/A	40.56
Total	**564**	**3.4**	**389,122**	**8.7**	**45.56**

Exhibit 62 provides detailed information about the amount of pollutants by vehicle class.

Exhibit 62: MCPS Vehicle Fleet Pollutants Emitted – FY 02

Vehicle Class	NO_x (Tons)	NMHC (Tons)	PM (Tons)	NO_x (%)	VOC (%)	PM (%)
Passenger Cars	0.91	0.43	0.21	2%	6%	14%
Light Trucks	2.06	1.01	0.38	6%	13%	25%
Heavy Trucks	33.49	6.15	0.92	92%	81%	61%
Total	**36.46**	**7.59**	**1.51**	**100%**	**100%**	**100%**

In addition to the emission information presented in the body of the report, OLO calculated several other measurements to analyze the emissions of each agency's fleet. The following pages of the appendix present data for the MCPS fleet. The measures include:

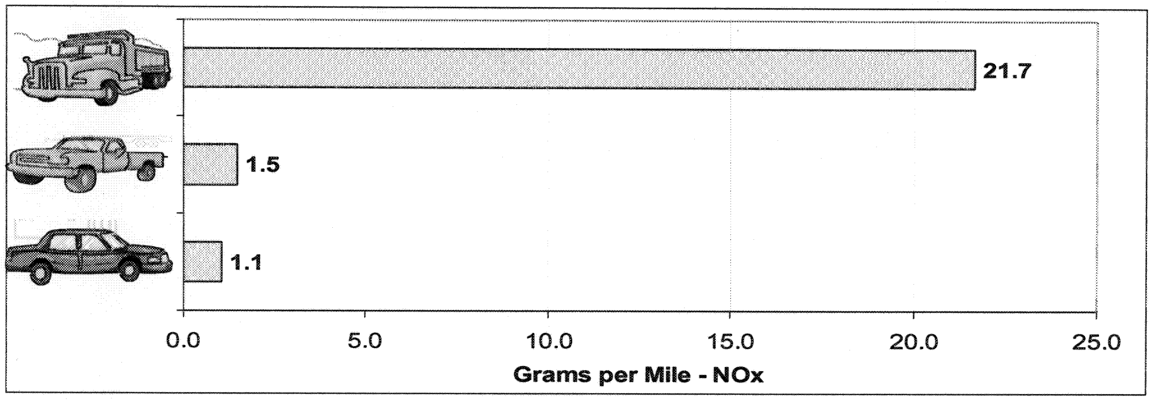
- Emission rates per mile by vehicle class;
- Average amounts of pollutants by vehicle class;
- The pollutants of pre-1994 vehicles as a percent of total fleet pollutants, and
- The relationship between specific pollutants and vehicle miles traveled by vehicle class.

1. Emission Rates per Mile

The rate at which a vehicle produces NO_x, VOC, and PM depends on the class of vehicle and the vehicle age. Exhibits 63, 64, and 65 show the average rate per mile of the pollutants produced for a passenger car, a light truck, and a heavy truck in the MCPS fleet.

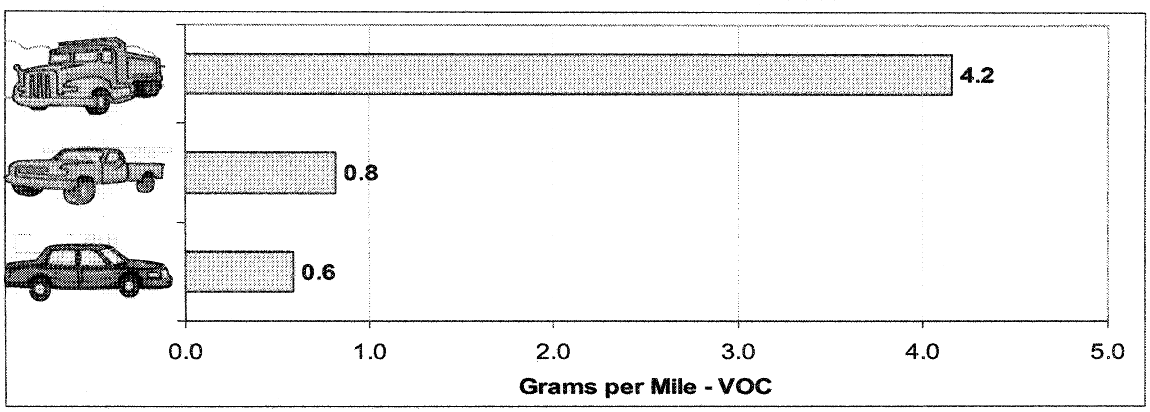
The exhibits show heavy trucks emit all pollutants at significantly greater rates that passenger cars or light trucks.

EXHIBIT 63: GRAMS OF NO_X EMITTED PER MILE IN FY 02



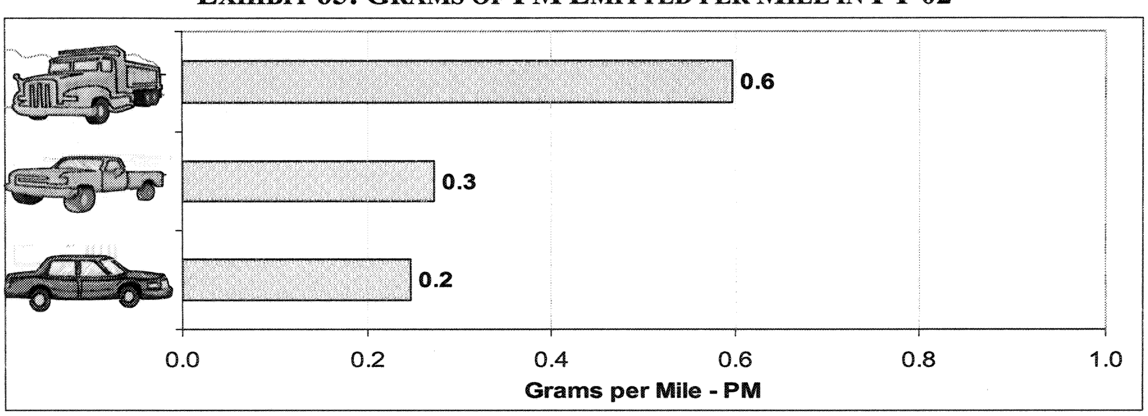
Source: OLO April, 2003

EXHIBIT 64: GRAMS OF VOC EMITTED PER MILE IN FY 02



Source: OLO April, 2003

EXHIBIT 65: GRAMS OF PM EMITTED PER MILE IN FY 02



Source: OLO April, 2003

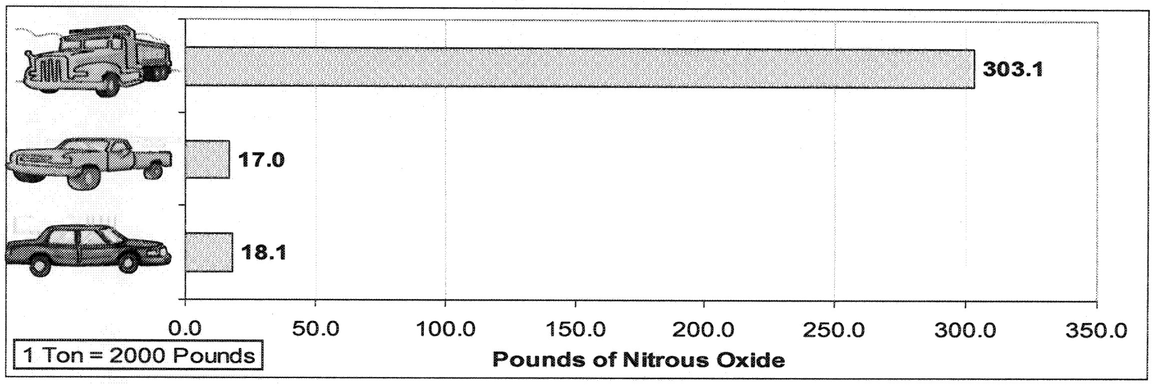
2. Amount of NO_x, VOC, and PM for an Average Vehicle

Exhibits 66, 67, and 68 present the emissions of NO_x, VOC, and PM for a passenger car, a light truck, and a heavy truck in the MCPS fleet taking into account the vehicle miles traveled in FY 02. These graphs show:

- On average, a heavy truck emits nearly 18 times the amount of NO_x and 8 times the amount of VOC than a light truck,

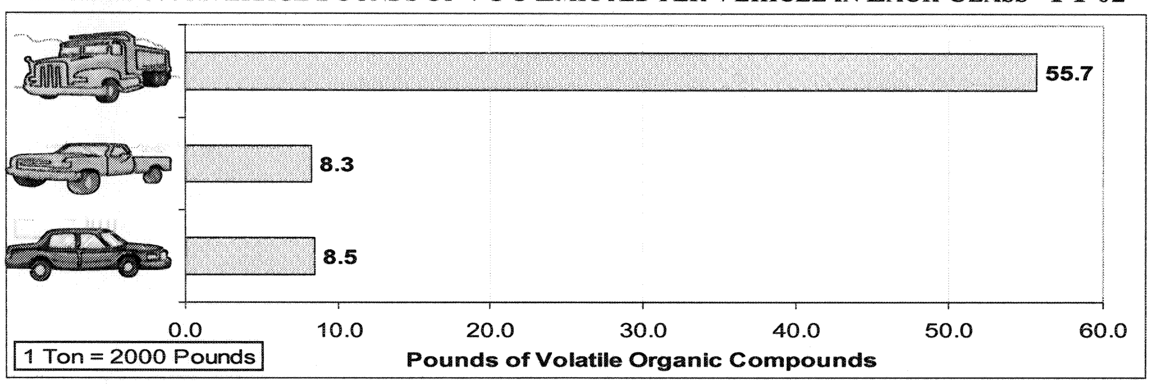
- On average, a heavy truck emits 2.5 times the amount of PM than a light truck and 2 times the amount of PM than a passenger car.

EXHIBIT 66: AVERAGE POUNDS OF NO_X EMITTED PER VEHICLE IN EACH CLASS - FY 02



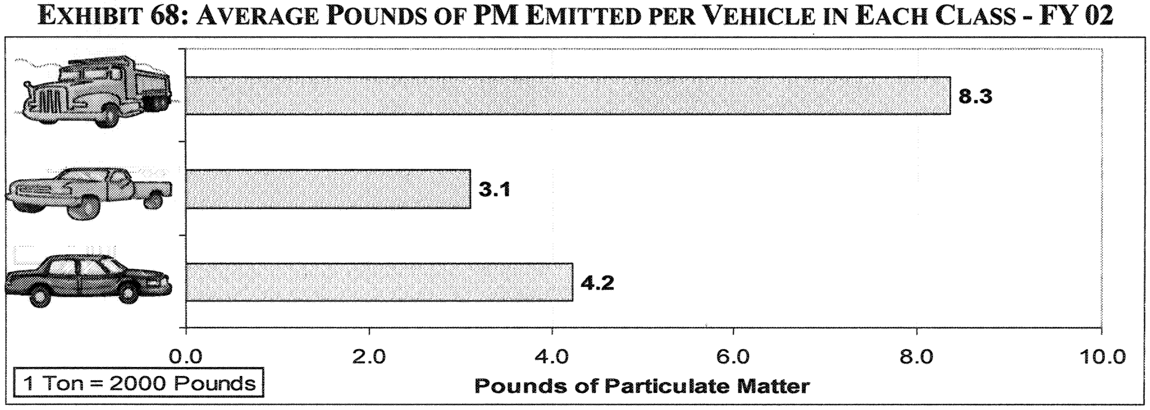
Source: OLO April, 2003

EXHIBIT 67: AVERAGE POUNDS OF VOC EMITTED PER VEHICLE IN EACH CLASS - FY 02



Source: OLO April, 2003

EXHIBIT 68: AVERAGE POUNDS OF PM EMITTED PER VEHICLE IN EACH CLASS - FY 02

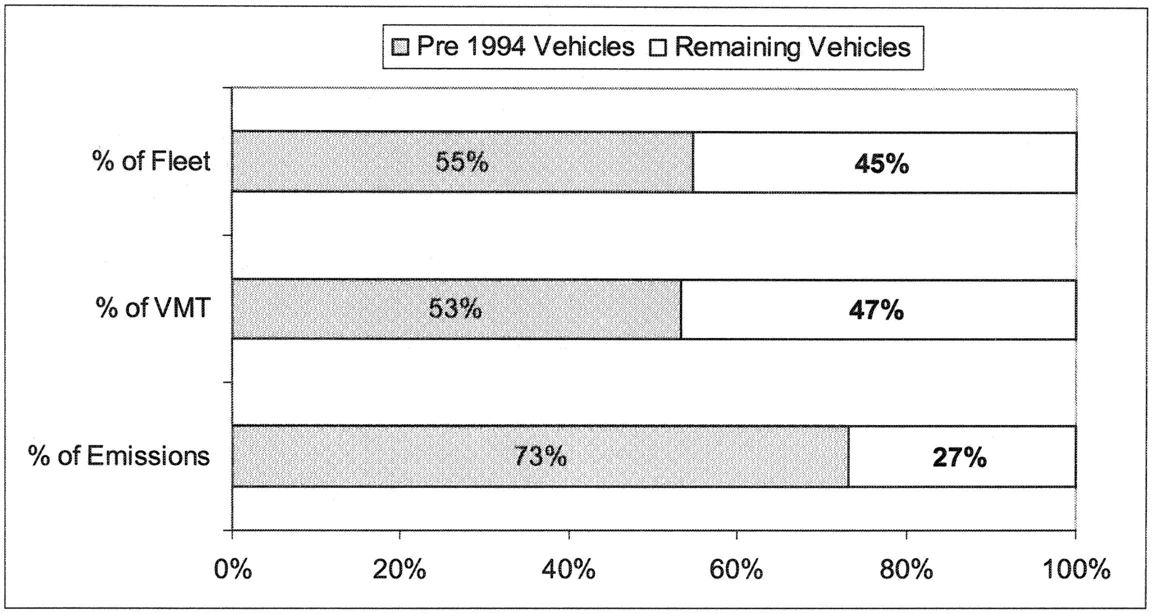


Source: OLO April, 2003

3. Pre-1994 Vehicles and Emission Levels

OLO calculated the amount of pollution emitted by MCPS' 309 pre-1994 vehicles which account for 55% of the total fleet and 53% of the total mileage. OLO found these vehicles account for 73% of the fleet's total emissions.

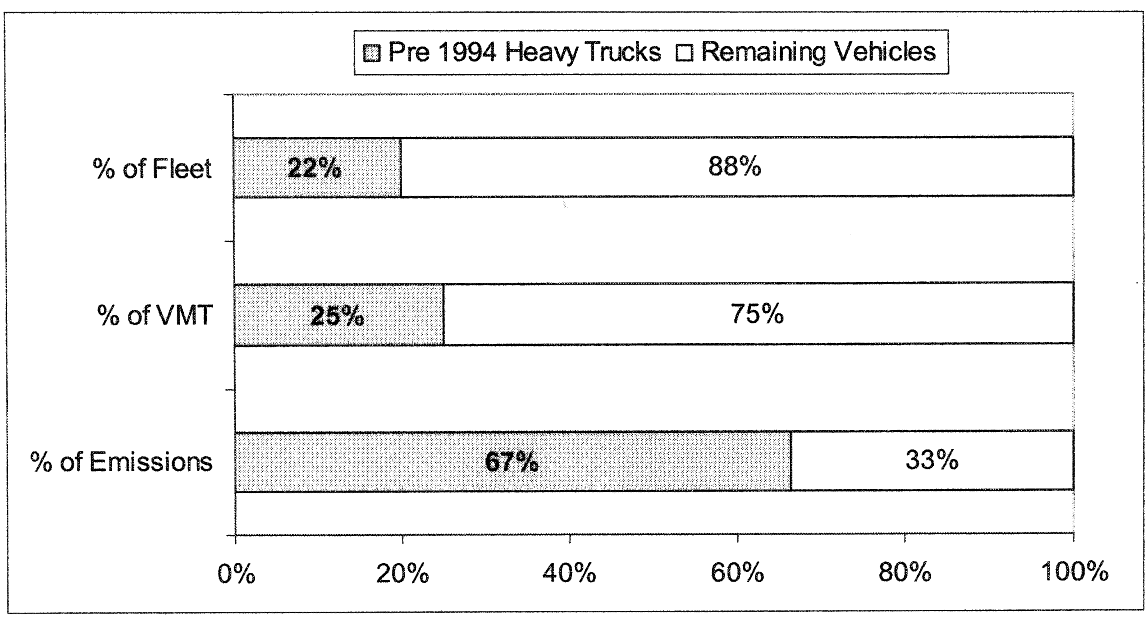
EXHIBIT 69: IMPACT OF PRE-1994 VEHICLES ON FLEET EMISSIONS IN FY 02



Source: OLO April, 2003

OLO also calculated the amount of pollution emitted by MCPS' pre-1994 heavy trucks. Exhibit 70 shows these 123 older trucks account for 22% of the total fleet, 25% of the total mileage, and 67% of the total emissions. OLO believes that the pre-1994 heavy truck emissions are significant given the relatively small number of miles traveled by these vehicles.

EXHIBIT 70: IMPACT OF PRE-1994 HEAVY TRUCKS ON FLEET EMISSIONS IN FY 02

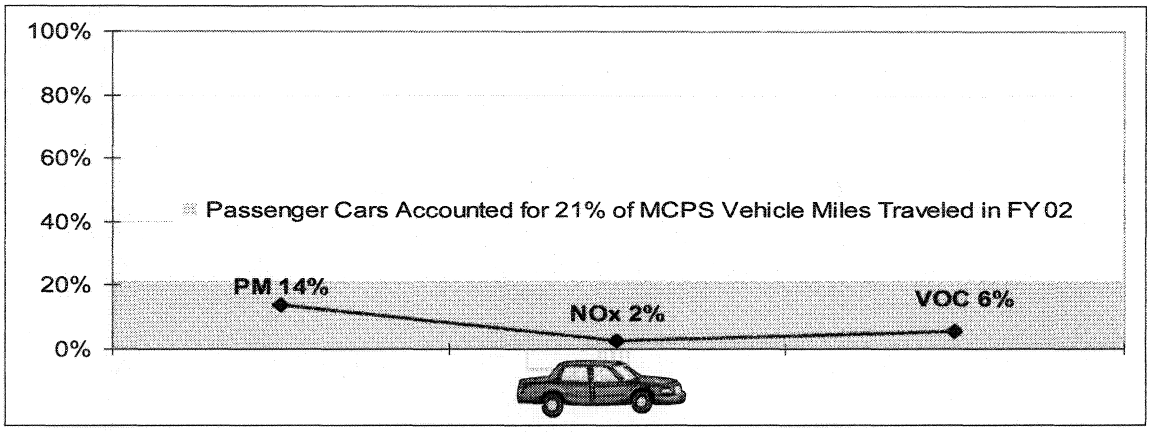


Source: OLO April, 2003

4. Emission Levels and Vehicle Miles Traveled by Vehicle Class

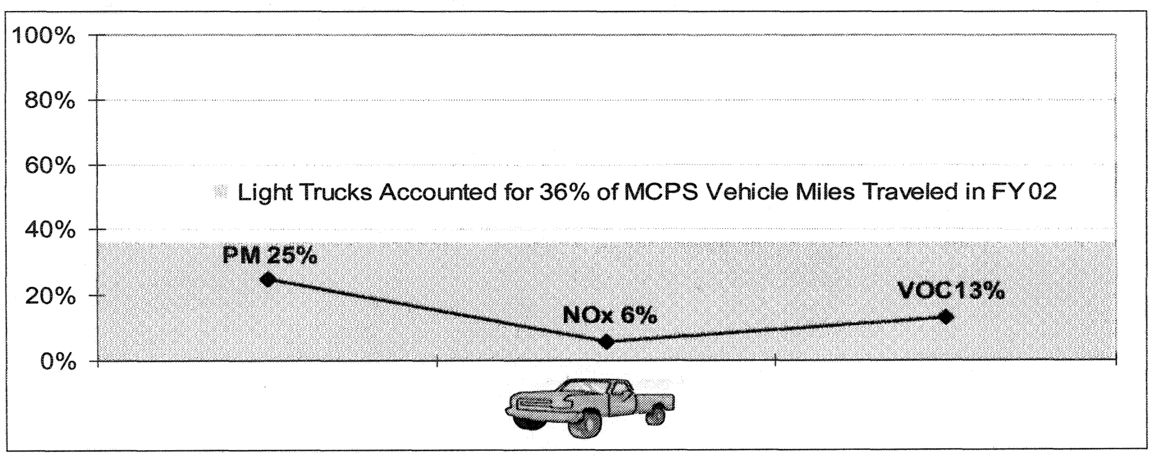
OLO examined the relationship between specific pollutants and vehicle miles traveled for each vehicle class. OLO found passenger cars and light trucks emit a disproportionately lower share of pollutants than heavy trucks. These results are summarized in Exhibits 71, 72, and 73 below.

EXHIBIT 71: PASSENGER CARS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



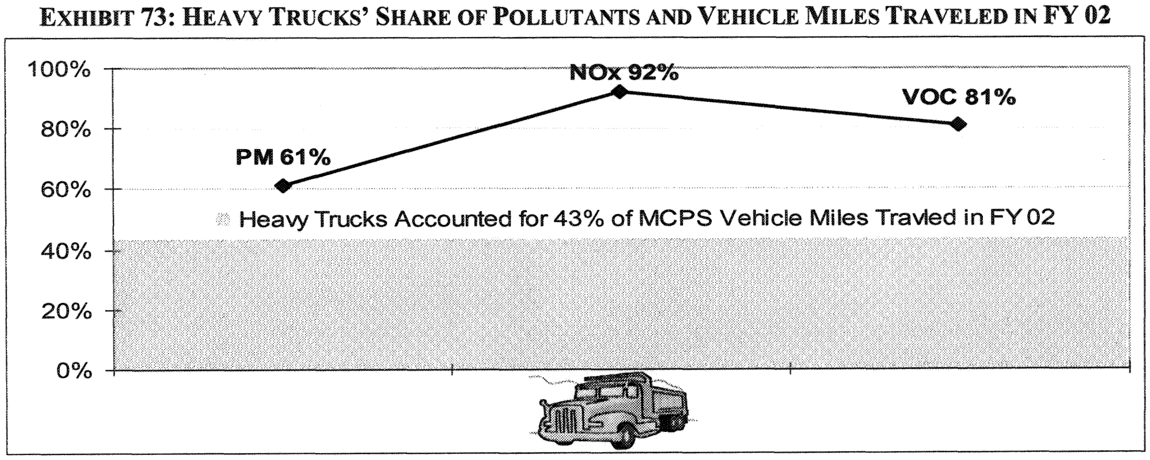
Source: OLO April, 2003

EXHIBIT 72: LIGHT TRUCKS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



Source: OLO April, 2003

EXHIBIT 73: HEAVY TRUCKS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



Source: OLO April, 2003

DETAILS OF MARYLAND NATIONAL CAPITOL PARK AND PLANNING COMMISSION (M-NCPPC) ON-ROAD CAR AND TRUCK FLEET

In FY 02, M-NCPPC maintained a fleet of 528 vehicles that traveled 4.6 million miles, used 371,000 gallons of fuel, and operated at an overall fuel efficiency of 12.4 miles per gallon.

EXHIBIT 74: M-NCPPC VEHICLE FLEET COMPOSITION AND POLLUTANTS - FY 02[1]

Vehicle Class	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel	Miles per Gallon	Total Emissions (Tons)
Passenger Cars	154	1.8	106,508	16.9	1.77
Light Trucks	198	1.6	112,676	14.2	3.23
Heavy Trucks	176	1.2	151,899	7.9	26.25
Totals	**528**	**4.6**	**371,083**	**12.4**	**31.25**

Source: M-NCPPC and OLO April, 2003

1. The data shown in the "Gallons of Fuel" and the "Miles Per Gallon" columns are based on estimates developed by both M-NCPPC and OLO staff.

Exhibit 75 provides detailed information about the amount of pollutants by vehicle sub-fleet.

EXHIBIT 75: M-NCPPC FLEET – POLLUTANTS EMITTED FY 02

Vehicle Class	NO_x (Tons)	NMHC (Tons)	PM (Tons)	NO_x (%)	VOC (%)	PM (%)
Passenger Cars	1.01	0.55	0.21	4%	8%	22%
Light Trucks	1.99	0.96	0.28	8%	13%	30%
Heavy Truck	20.66	5.13	0.46	88%	79%	48%
Total	**23.66**	**6.64**	**0.95**	**100%**	**100%**	**100%**

Source: OLO April, 2003

In addition to the emission information presented in the body of the report, OLO calculated several other measures to analyze the emissions of each agency's fleet. The following pages of the appendix present data for the M-NCPPC fleet. The measures include:

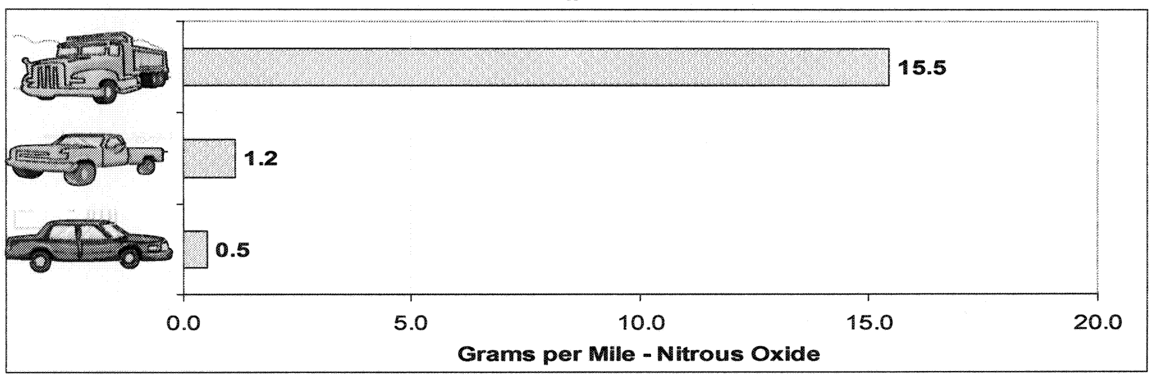
- Emission rates per mile by vehicle type
- Average amounts of pollutants by vehicle type taking into account FY 2002 mileage
- The pollutants of pre-1994 vehicles as a percent of total fleet pollutants, and
- The relationship between a specific pollutant and vehicle miles traveled by vehicle type.

1. Emission Rates per Mile

The rate at which a vehicle produces pollutants depends on the type of vehicle and the vehicle age. Exhibits 76, 77, and 78 show the average rate per mile of NO_x, VOC, and PM produced for a passenger car, a light truck and a heavy truck in the M-NCPPC fleet.

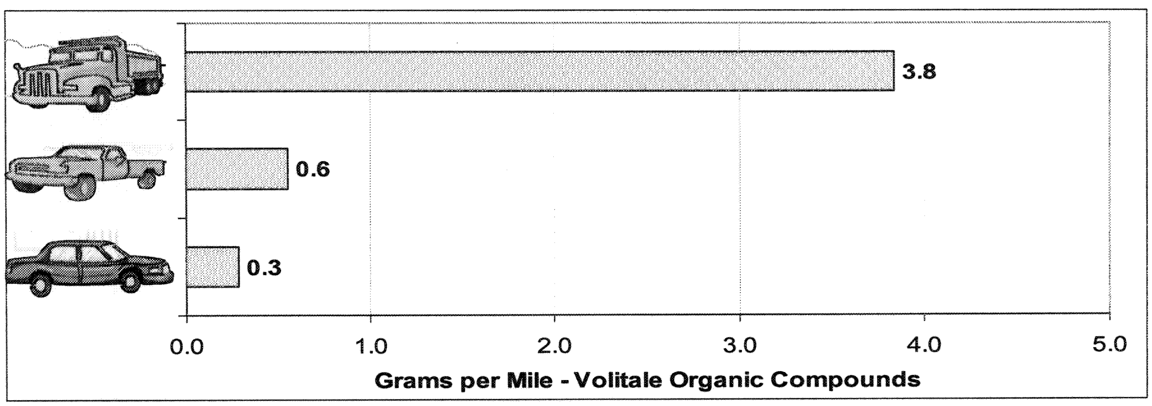
The exhibits show heavy trucks emit all pollutants at significantly greater rates than passenger cars or light trucks.

EXHIBIT 76: GRAMS OF NO_X EMITTED PER MILE IN FY 02



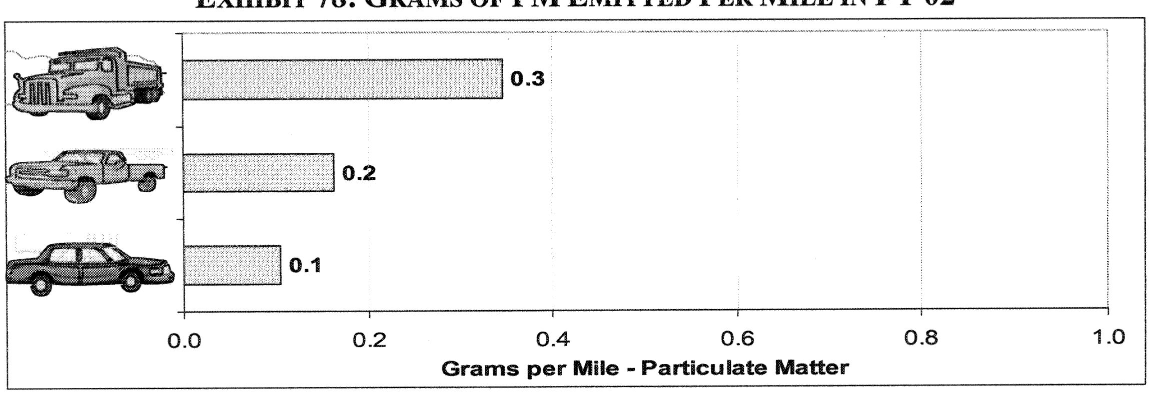
Source: OLO April, 2003

EXHIBIT 77: GRAMS OF VOC EMITTED PER MILE IN FY 02



Source: OLO April, 2003

EXHIBIT 78: GRAMS OF PM EMITTED PER MILE IN FY 02



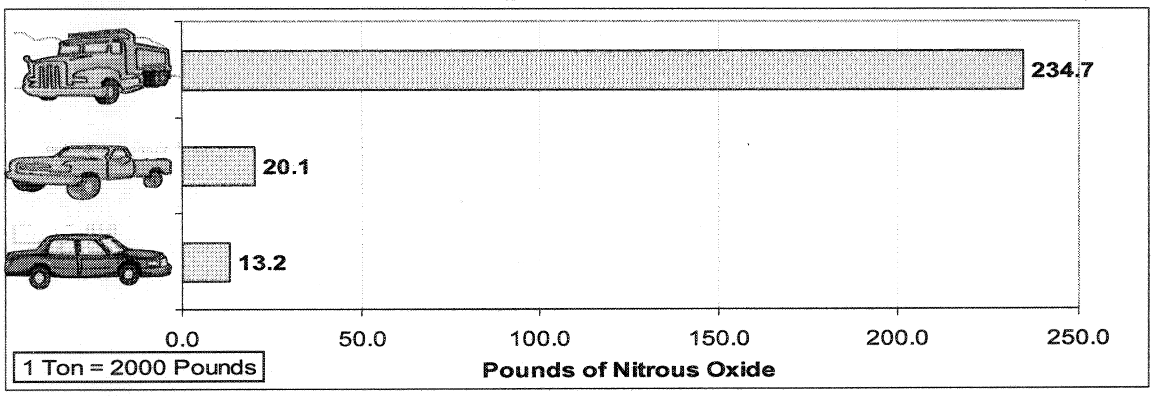
Source: OLO April, 2003

2. Amount of NO_x, VOC, and PM for an Average Vehicle

Exhibits 79, 80 and 81 present the emissions of NO_x, VOC, and PM for a passenger car, a light truck, and a heavy truck in the M-NCPPC fleet taking into account the vehicle miles traveled in FY 2002. These graphs show:

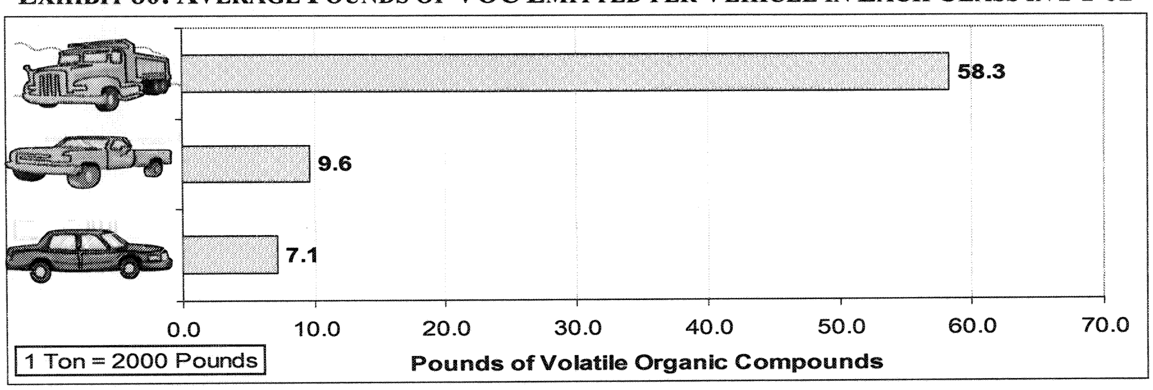
- On average, a heavy truck emitted ten times the amount of nitrogen oxide and 6 times the amount of hydrocarbons than a light truck
- On average, a heavy truck emitted three times the amount of particulate matter than a light truck or a passenger car.

EXHIBIT 79: AVERAGE POUNDS OF NO_X EMITTED PER VEHICLE IN EACH CLASS IN FY 02



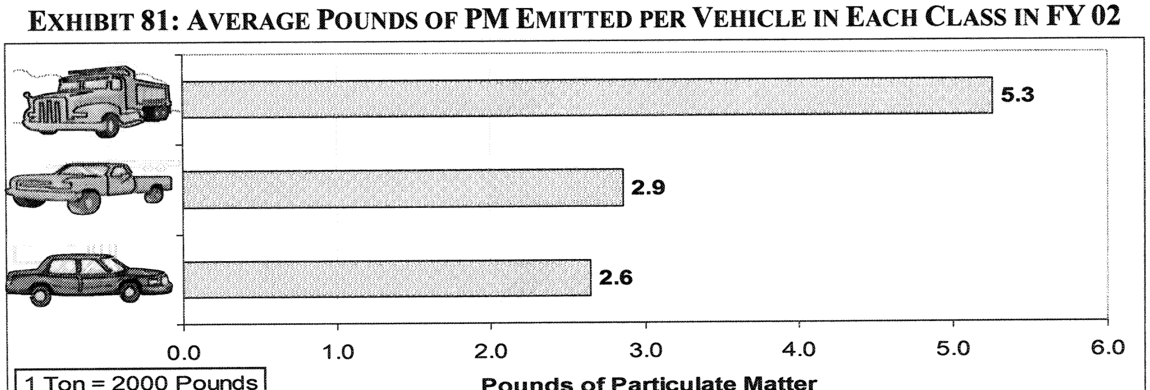
Source: OLO April, 2003

EXHIBIT 80: AVERAGE POUNDS OF VOC EMITTED PER VEHICLE IN EACH CLASS IN FY 02



Source: OLO April, 2003

EXHIBIT 81: AVERAGE POUNDS OF PM EMITTED PER VEHICLE IN EACH CLASS IN FY 02

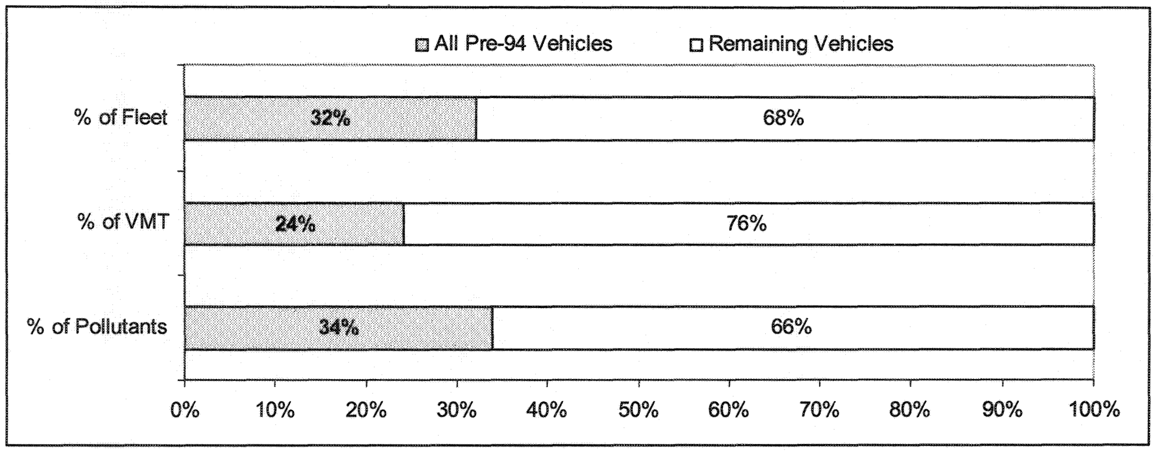


Source: OLO April, 2003

3. Pre-1994 Vehicles and Emission Levels

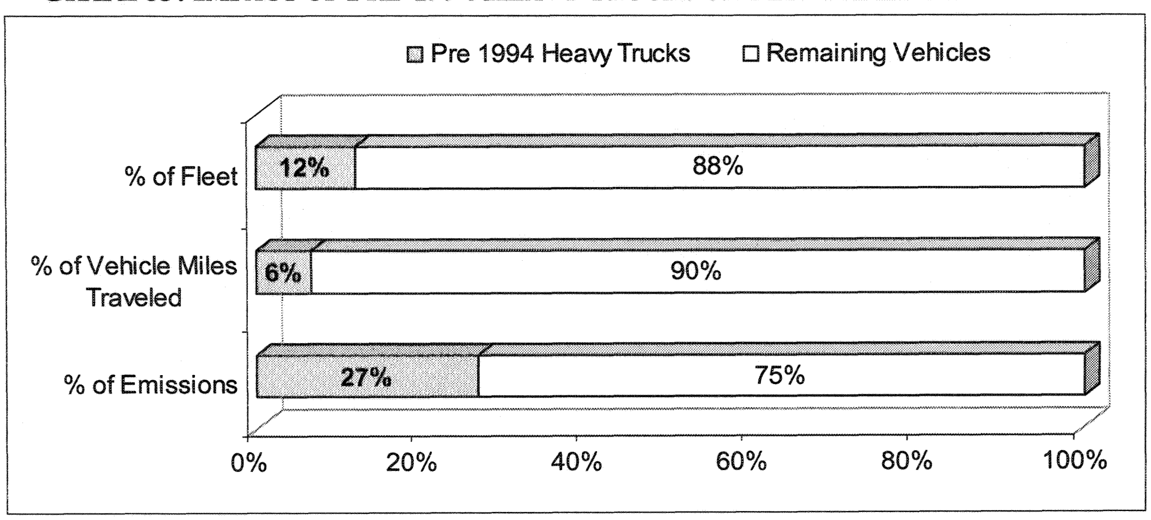
OLO calculated the amount of pollution emitted by M-NCPPC's pre-1994 vehicles which account for nearly a third of the total fleet and 24% of the total mileage. OLO found these vehicles account for 34% of the fleet's total emissions.

EXHIBIT 82: IMPACT OF PRE-1994 VEHICLES ON M-NCPPC EMISSIONS IN FY 02



OLO also calculated the amount of pollution emitted by M-NCPPC's pre-1994 heavy trucks. Exhibit 83 shows these 65 older trucks account for 12% of the total fleet, 6% of the total mileage and 27% of the total emissions. OLO believes that the pre-1994 heavy truck emissions are significant given the relatively small number of miles traveled by these vehicles.

GRAPH 83: IMPACT OF PRE-1994 HEAVY TRUCKS ON FLEET EMISSIONS IN FY 02

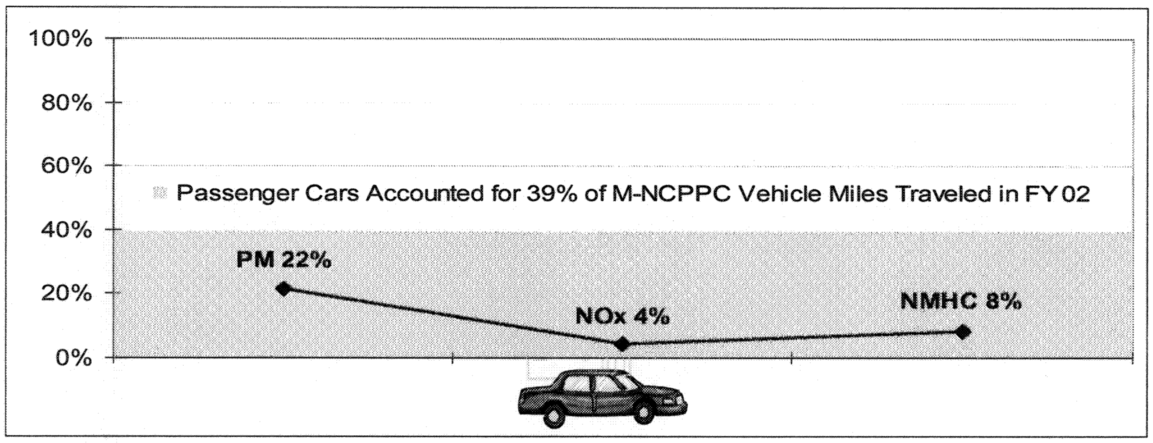


Source: OLO April, 2003

4. Emission Levels and Vehicle Miles Traveled by Vehicle Class

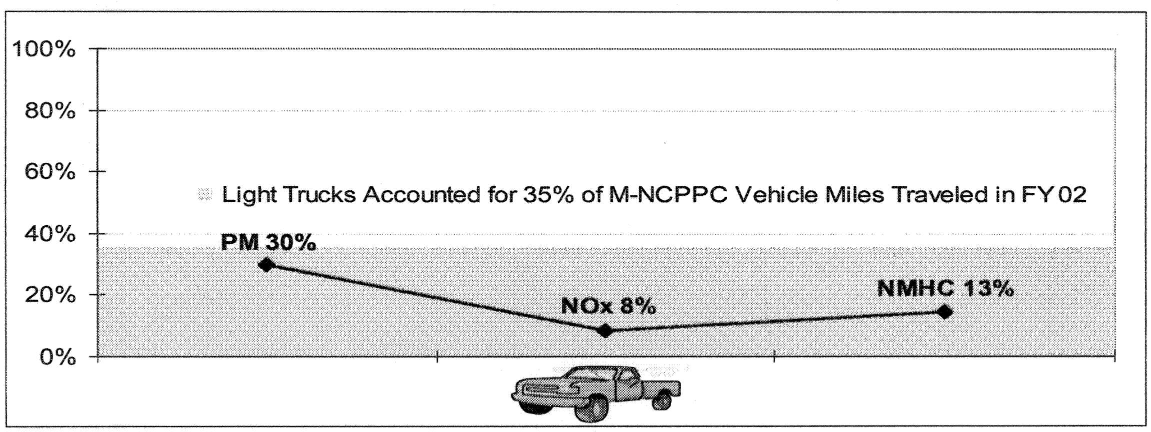
OLO examined the relationship between specific pollutants and vehicle miles traveled for each vehicle class. OLO found passenger cars and light trucks emit a disproportionately lower share of pollutants than heavy trucks. These results are summarized in the exhibits 84, 85 and 86.

EXHIBIT 84: PASSENGER CARS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



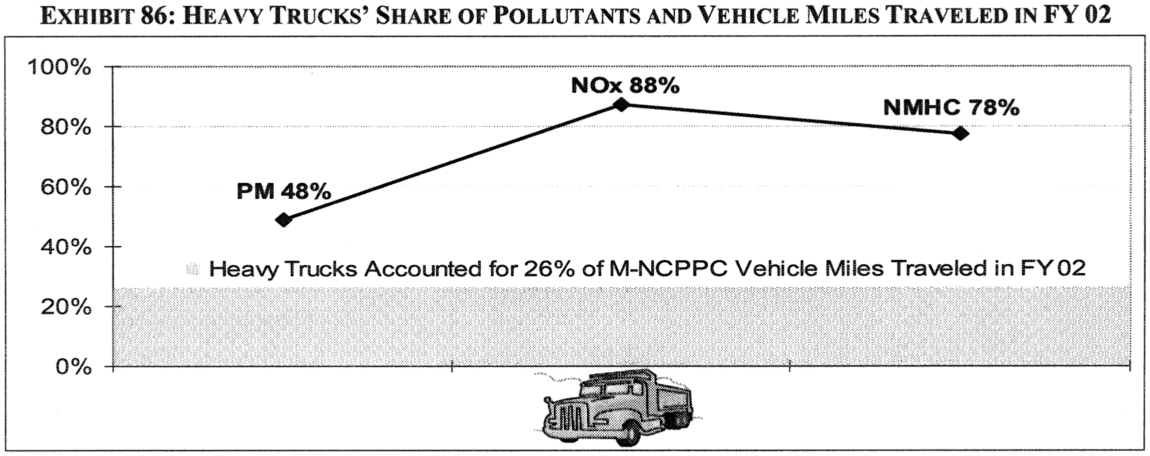
Source: OLO April, 2003

EXHIBIT 85: LIGHT TRUCKS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



Source: OLO April, 2003

EXHIBIT 86: HEAVY TRUCKS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



Source: OLO April, 2003

DETAILS OF MONTGOMERY COLLEGE (MC) ON-ROAD CAR AND TRUCK FLEET

In FY 02, MC maintained a fleet of 44 vehicles that traveled 185,000 miles, and emitted 1.70 tons of pollutants.

The characteristics of the MC fleet are summarized below.

EXHIBIT 87: MC VEHICLE FLEET COMPOSITION AND POLLUTANTS - FY 02

Vehicle Class	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel	Miles per Gallon	Total Emissions (Tons)
Passenger Cars	1	18,000	N/A	N/A	0.02
Light Trucks	21	89,000	N/A	N/A	0.18
Heavy Trucks	22	78,000	N/A	N/A	1.50
Totals	**44**	**185,000**	**N/A**	**N/A**	**1.70**

Source: MC and OLO April, 2003

Exhibit 88 provides detailed information about the amount of pollutants by vehicle sub-fleet.

EXHIBIT 88: MC FLEET POLLUTANTS EMITTED - FY 02

Vehicle Class	NO_x (Tons)	VOC (Tons)	PM (Tons)	NO_x (%)	VOC (%)	PM (%)
Passenger Cars	0.01	0.01	0.00	1%	2%	0%
Light Trucks	0.11	0.05	0.02	9%	13%	40%
Heavy Trucks	1.14	0.33	0.03	90%	85%	60%
Total	**1.26**	**0.39**	**0.05**	**100%**	**100%**	**100%**

Source: OLO April, 2003

In addition to the emission information presented in the body of the report, OLO calculated several other measures to analyze the emissions of each agency's fleet. The following pages of the appendix present data for the MC fleet. The measures include:

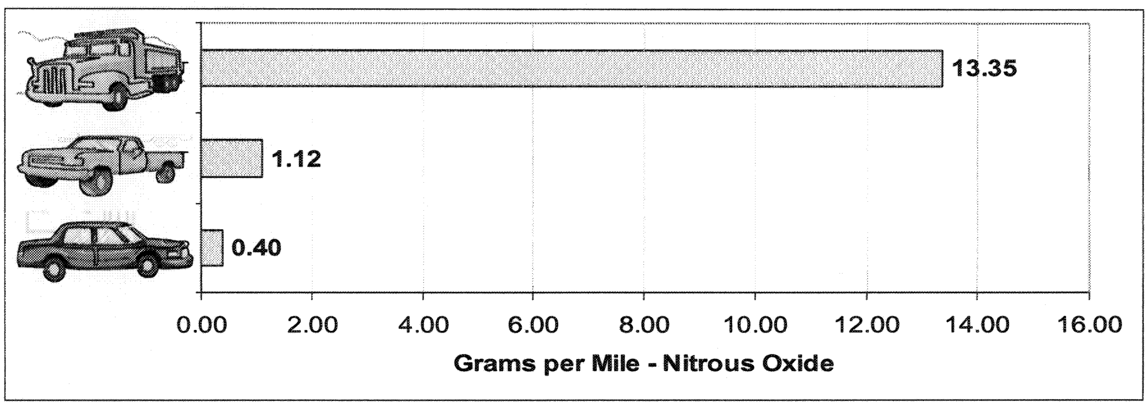
- Emission rates per mile by vehicle type
- Average amounts of pollutants by vehicle type taking into account FY 02 mileage
- The pollutants of pre-1994 vehicles as a percent of total fleet pollutants, and
- The relationship between a specific pollutant and vehicle miles traveled by vehicle type.

1. Emission Rates per Mile

The rate at which a vehicle produces NO_x, VOC, and PM depends on the type of vehicle and the vehicle age. Exhibits 89, 90 and 91 show the average rate per mile of the pollutants produced for a passenger car, a light truck and a heavy truck in the MC fleet.

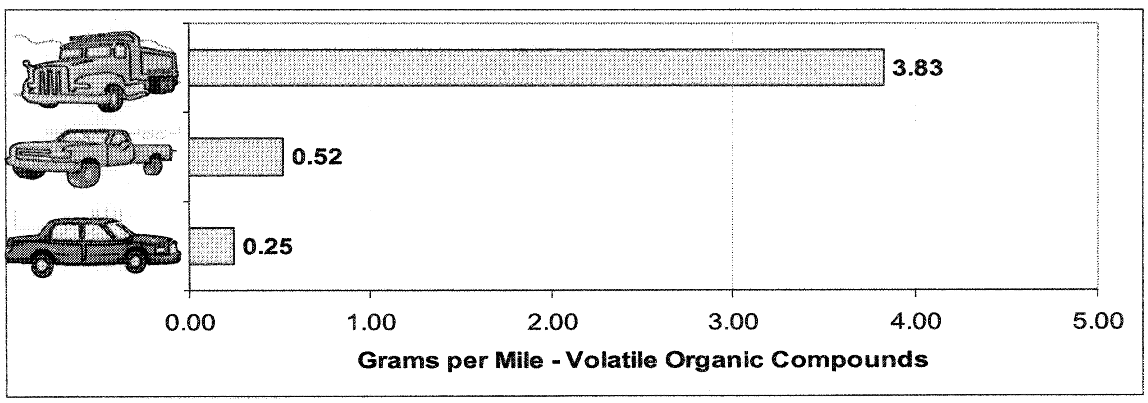
The exhibits show heavy trucks emit all pollutants at significantly greater rates than passenger cars or light trucks.

EXHIBIT 89: GRAMS OF NO_X EMITTED PER MILE IN FY 02



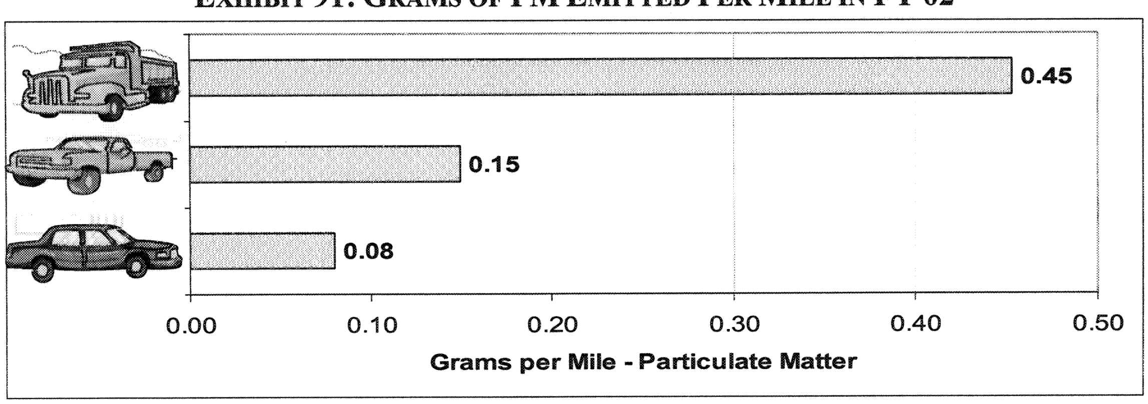
Source: OLO April, 2003

EXHIBIT 90: GRAMS OF VOC EMITTED PER MILE IN FY 02



Source: OLO April, 2003

EXHIBIT 91: GRAMS OF PM EMITTED PER MILE IN FY 02



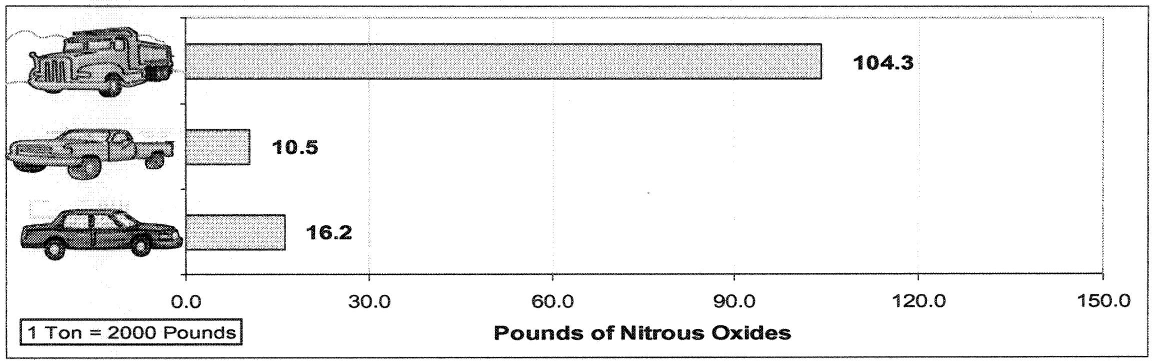
Source: OLO April, 2003

2. Emissions of NO_x, VOC, and PM per Vehicle

Exhibits 92, 93, and 94 present the emissions of NO_x, VOC, and PM for a passenger car, a light truck, and a heavy truck in the MC fleet taking into account the vehicle miles traveled in FY 02. These graphs show:

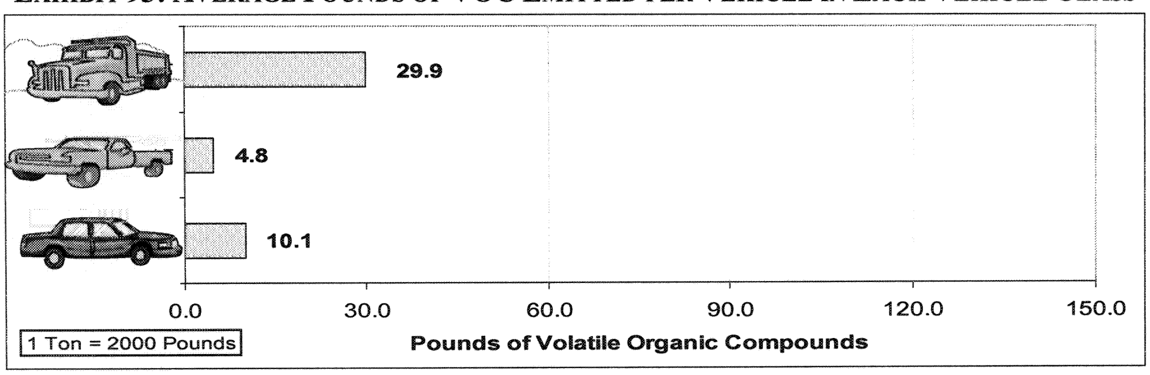
- On average, a heavy truck emits nearly ten times the amount of NO_x and six times the amount of VOC than a light truck,
- On average, a heavy truck emits two and a half times the amount of PM than a light truck and the same amount as a passenger car.

EXHIBIT 92: AVERAGE POUNDS OF NO_x EMITTED PER VEHICLE IN EACH VEHICLE CLASS



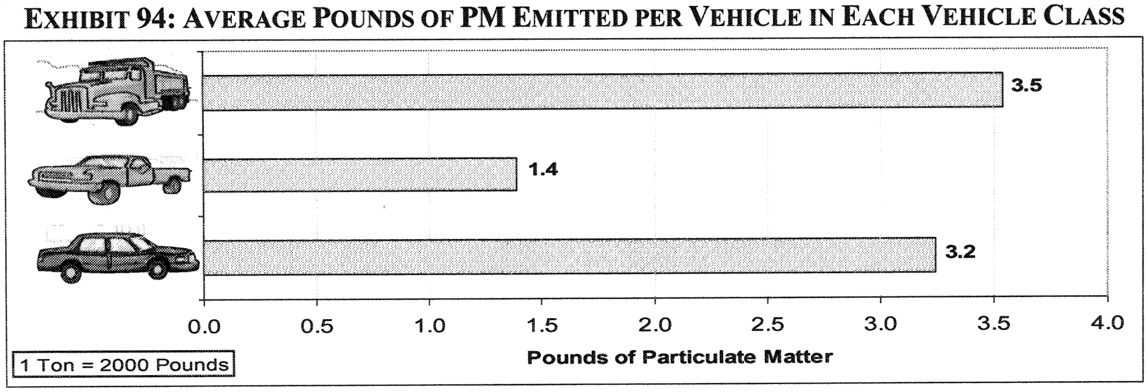
Source: OLO April, 2003

EXHIBIT 93: AVERAGE POUNDS OF VOC EMITTED PER VEHICLE IN EACH VEHICLE CLASS



Source: OLO April, 2003

EXHIBIT 94: AVERAGE POUNDS OF PM EMITTED PER VEHICLE IN EACH VEHICLE CLASS

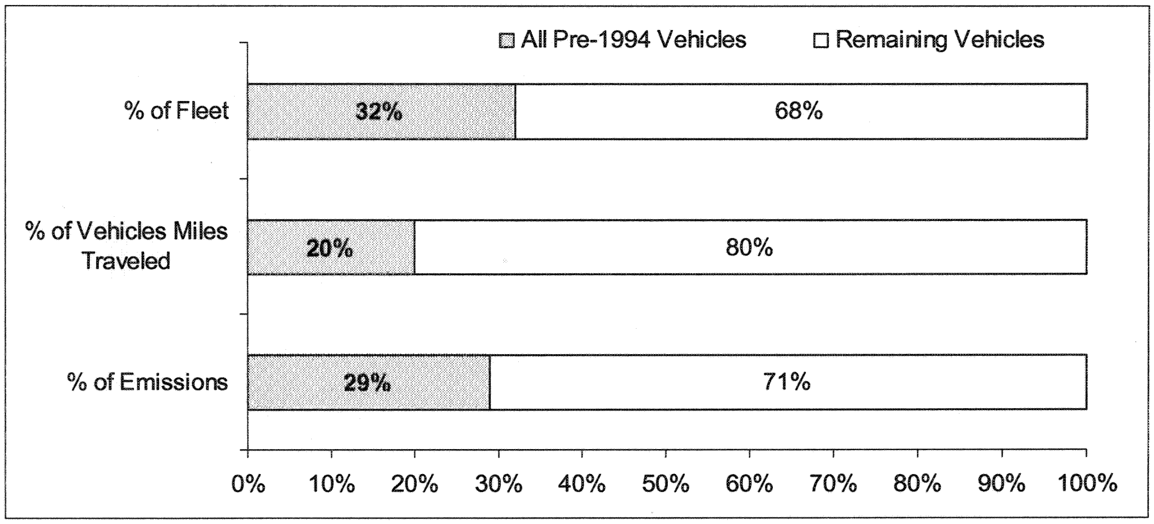


Source: OLO April, 2003

3. Vehicle Age and Emission Levels

OLO calculated the amount of pollution emitted by MC's 14 pre-1994 vehicles which account for 32% of the total fleet and 20% of the total mileage. OLO found these vehicles account for 29% of the fleet's total emissions.

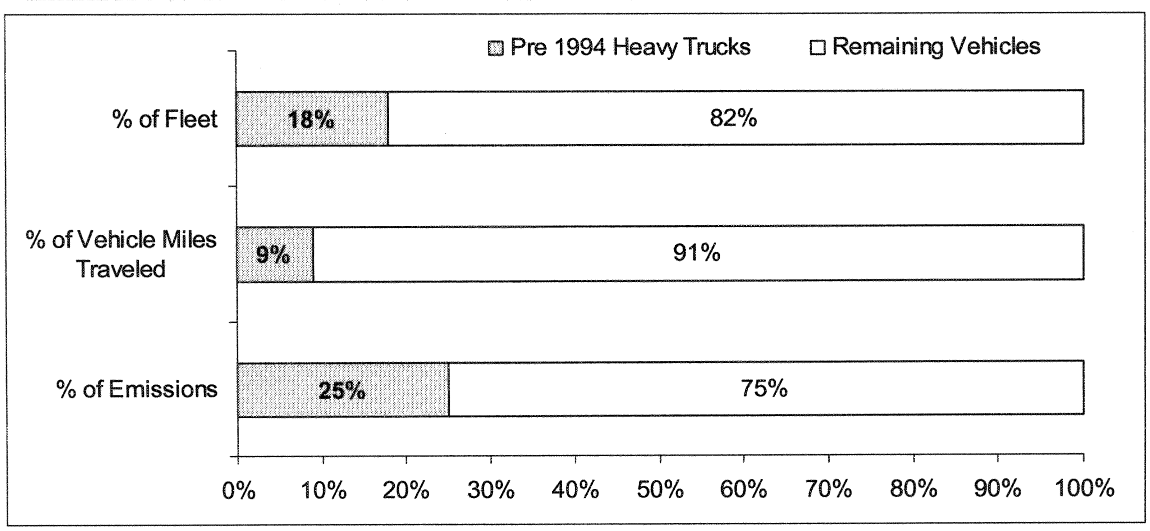
EXHIBIT 95: IMPACT OF PRE-1994 VEHICLES ON FLEET EMISSIONS IN FY 02



Source: OLO April, 2003

OLO also calculated the amount of pollution emitted by MC's pre-1994 heavy trucks. Exhibit 96 shows these eight older trucks account for 18% of the total fleet, 9% of the total mileage, and 25% of the total emissions. OLO believes that the pre-1994 heavy truck emissions are significant given the relatively small number of miles traveled by these vehicles.

EXHIBIT 96: IMPACT OF PRE–1994 HEAVY TRUCKS ON FLEET EMISSIONS IN FY 02

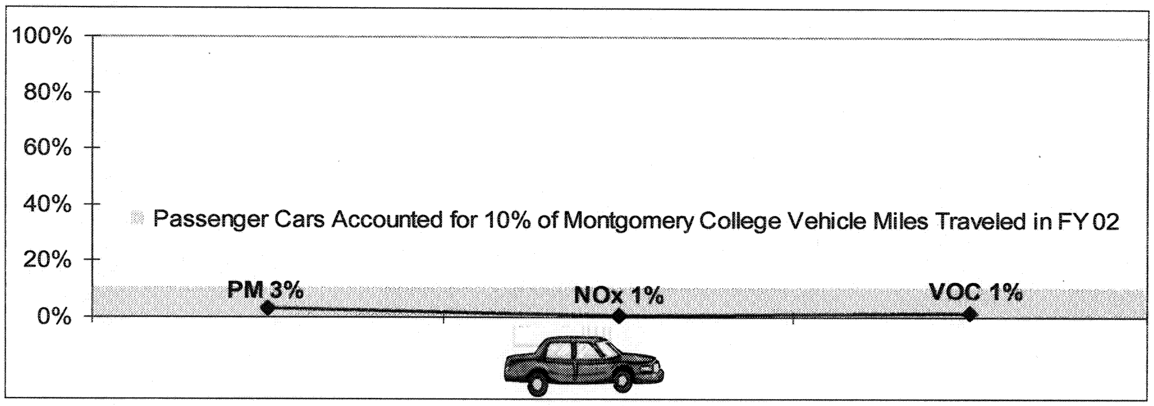


Source: OLO April, 2003

4. Emission Levels and Vehicle Miles Traveled by Vehicle Class

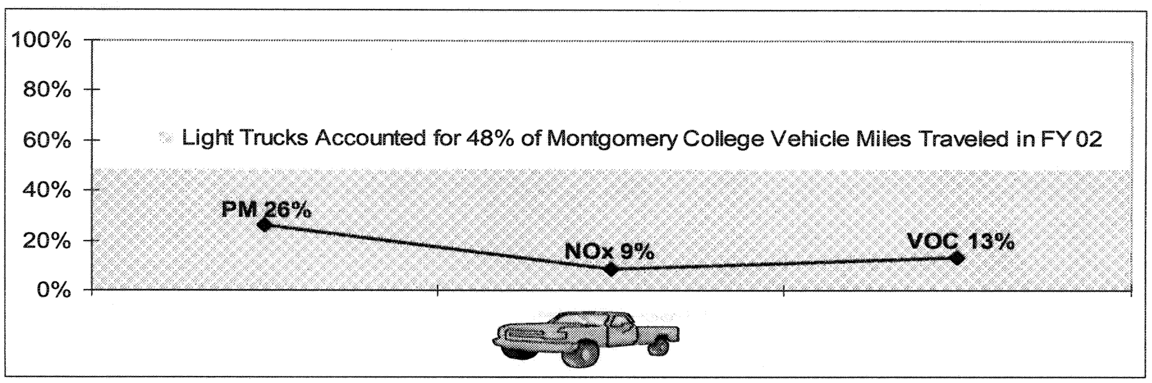
OLO examined the relationship between specific pollutants and vehicle miles traveled for each vehicle class. OLO found passenger cars and light trucks emit a disproportionately lower share of pollutants than heavy trucks. These results are summarized in the Exhibits 97, 98 and 99.[1]

EXHIBIT 97: PASSENGER CARS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



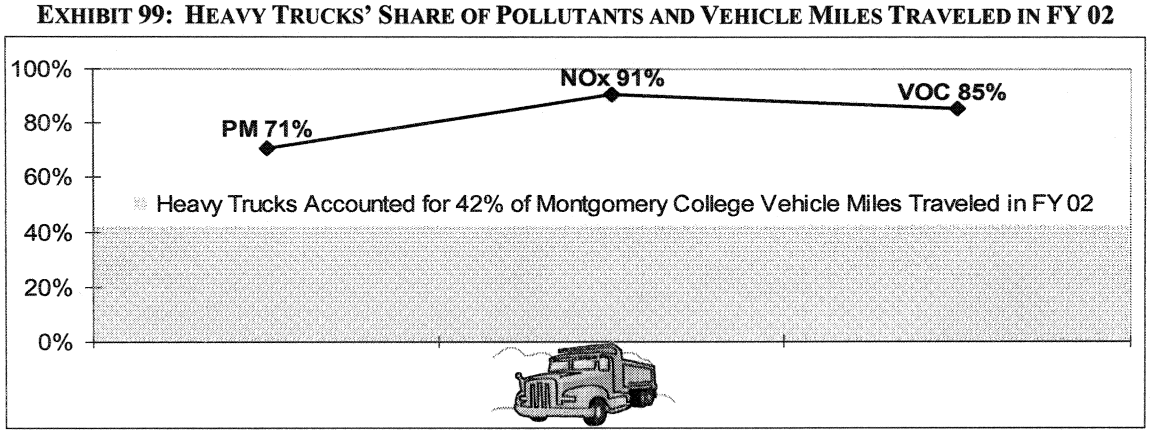
Source: OLO April, 2003

EXHIBIT 98: LIGHT TRUCKS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



Source: OLO April, 2003

EXHIBIT 99: HEAVY TRUCKS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



Source: OLO April, 2003

---

[1] Percentages for these exhibits may not match those on page 1 of this appendix due to the small number of pollutants present in the MC fleet.

DETAILS OF WASHINGTON SUBURBAN SANITARY COMMISSION (WSSC) ON-ROAD CAR AND TRUCK FLEET

In FY 02, WSSC maintained a fleet of 871[1] vehicles that traveled 8.0 million miles, used 548,000 gallons of fuel and operated at an overall efficiency of 14.6 miles per gallon.

The characteristics of the WSSC fleet are summarized below.

EXHIBIT 100: WSSC VEHICLE FLEET COMPOSITION AND POLLUTANTS - FY 02

SubFleet	# of Vehicles	Vehicle Miles Traveled (millions)	Gallons of Fuel	Miles per Gallon	Total Emissions (Tons)
Passenger Cars	122	0.8	26,000	31.0	0.90
Light Trucks	568	6.1	326,000	18.7	10.90
Heavy Trucks	181	1.1	196,000	5.6	18.70
Totals	**871**	**8.0**	**548,000**	**14.6**	**30.50**

Source: WSSC and OLO April, 2003

Exhibit 101 provides detailed information about the amount of pollutants by vehicle sub-fleet.

EXHIBIT 101: WSSC FLEET – POLLUTANTS EMITTED FY 02

Sub Fleet	NO_x (Tons)	VOC (Tons)	PM (Tons)	NO_x (%)	VOC (%)	PM (%)
Passenger Cars	0.5	0.3	0.1	2%	4%	6%
Light Trucks	6.9	3.2	0.8	33%	38%	47%
Heavy Truck	13.3	4.6	0.8	65%	58%	47%
Total	**20.7**	**8.1**	**1.7**	**100%**	**100%**	**100%**

Source: OLO April, 2003

In addition to the emission information presented in the body of the report, OLO calculated several other measures to analyze the emissions of each agency's fleet. The following pages of the appendix present data for the WSSC fleet. The measures include:

- Emission rates per mile by vehicle type;
- Average amounts of pollutants by vehicle type;
- The pollutants of pre-1994 vehicles as a percent of total fleet pollutants; and
- The relationship between a specific pollutant and vehicle miles traveled by vehicle type.

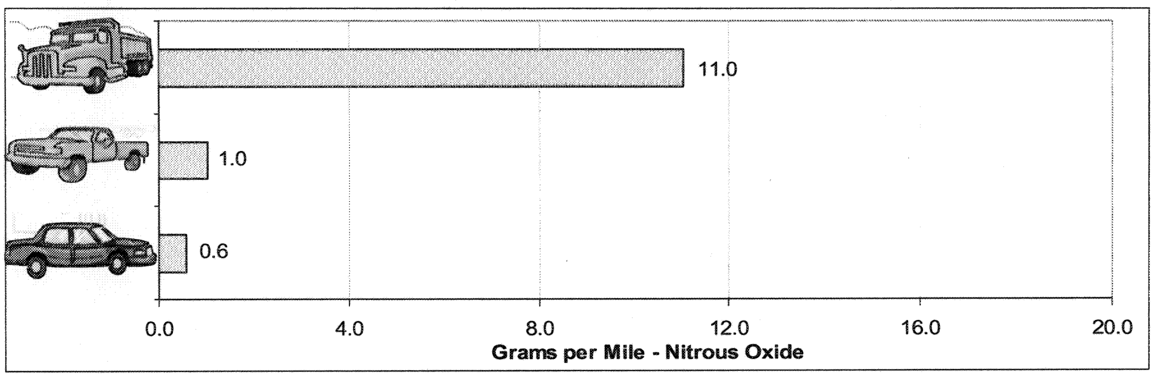
[1] There were 889 vehicles in WSSC's fleet in FY 02. OLO's "fleet" of 871 excludes 18 vehicles that were missing mileage data.

1. Emission Rates per Mile

The rate at which a vehicle produces pollutants depends on the type of vehicle and the vehicle age. Exhibits 102, 103, and 104 show the average rate per mile of NO_x, VOC, and PM produced for a passenger car, a light truck and a heavy truck in the WSSC fleet.

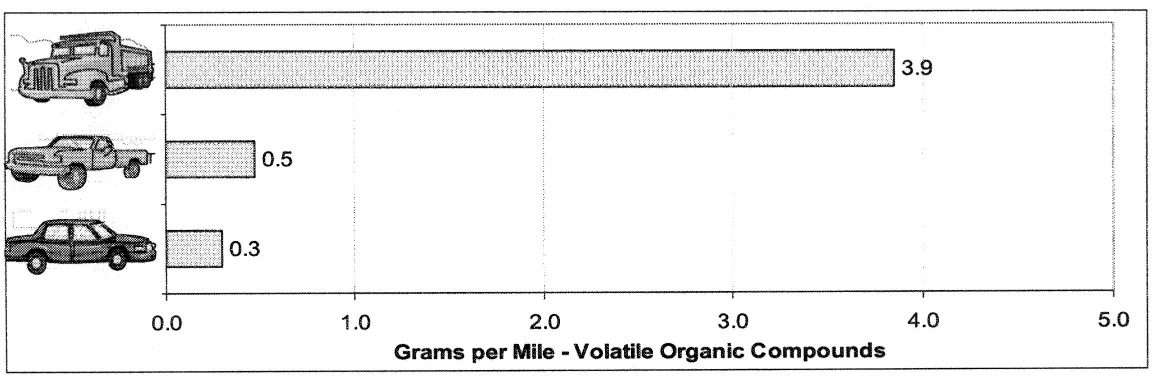
The graphs show heavy trucks emit all pollutants at significantly greater rates than passenger cars or light trucks.

EXHIBIT 102: GRAMS OF NO_X EMITTED PER MILE



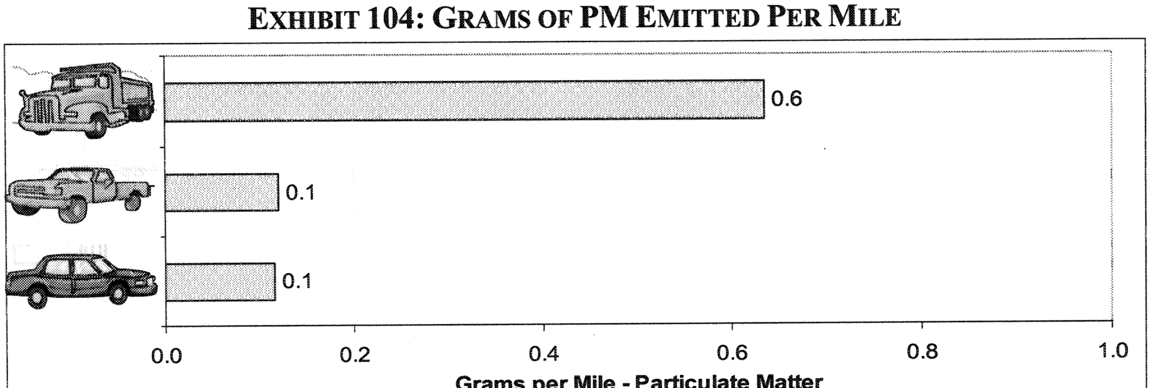
Source: OLO April, 2003

EXHIBIT 103: GRAMS OF VOC EMITTED PER MILE



Source: OLO April, 2003

EXHIBIT 104: GRAMS OF PM EMITTED PER MILE



Source: OLO April, 2003

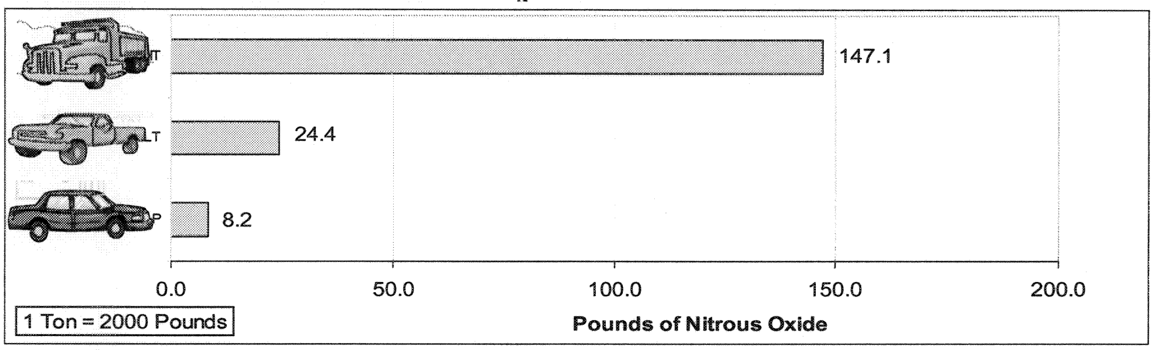
2. Amount of Pollutants Released by an Average Vehicle

Exhibits 105, 106 and 107 present the emissions of NO_x, VOC, and PM for a passenger car, a light truck, and a heavy truck in the WSSC fleet taking into account the vehicle miles traveled in FY 02. These graphs show:

- On average, a heavy truck emitted six times the amount of NO_x and five times the amount of VOC than a light truck.

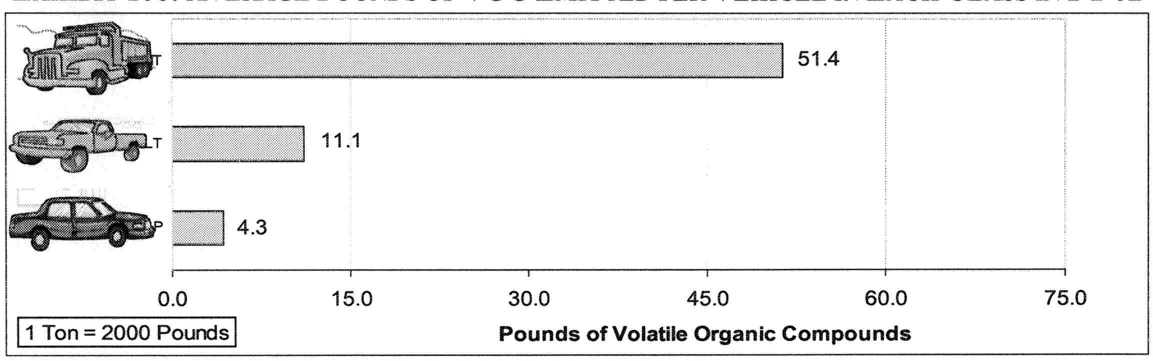
- On average, a heavy truck emits three times the amount of soot than a light truck and five times the amount of a passenger car.

EXHIBIT 105: AVERAGE POUNDS OF NO_x EMITTED PER VEHICLE IN EACH CLASS IN FY 02



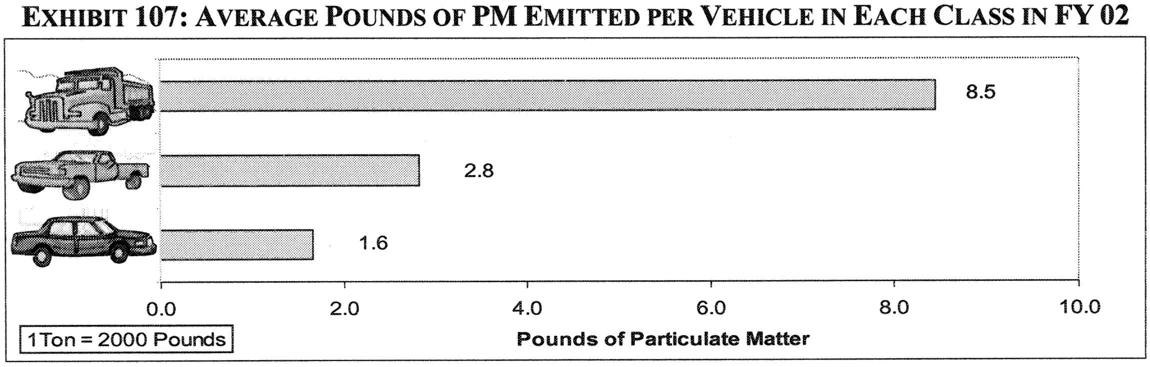
Source: OLO April, 2003

EXHIBIT 106: AVERAGE POUNDS OF VOC EMITTED PER VEHICLE IN EACH CLASS IN FY 02



Source: OLO April, 2003

EXHIBIT 107: AVERAGE POUNDS OF PM EMITTED PER VEHICLE IN EACH CLASS IN FY 02

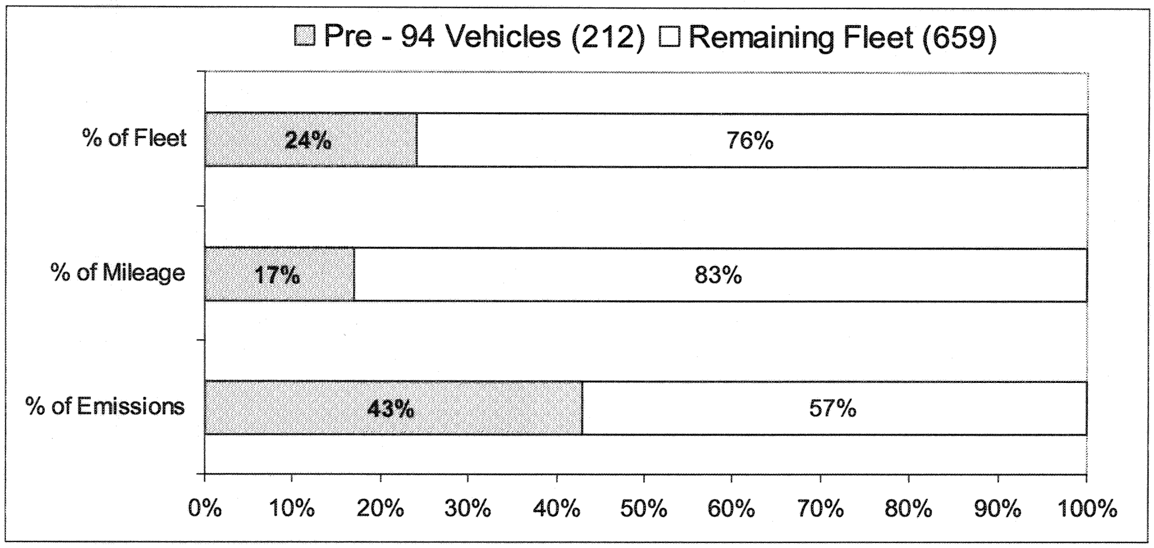


Source: OLO April, 2003

3. Pre-1994 Vehicles and Emission Levels

OLO calculated the amount of pollution emitted by WSSC's 212 pre-1994 vehicles that account for 24% of the total fleet and 17% of the total mileage. OLO found these vehicles account for 43% of the fleet's total emissions.

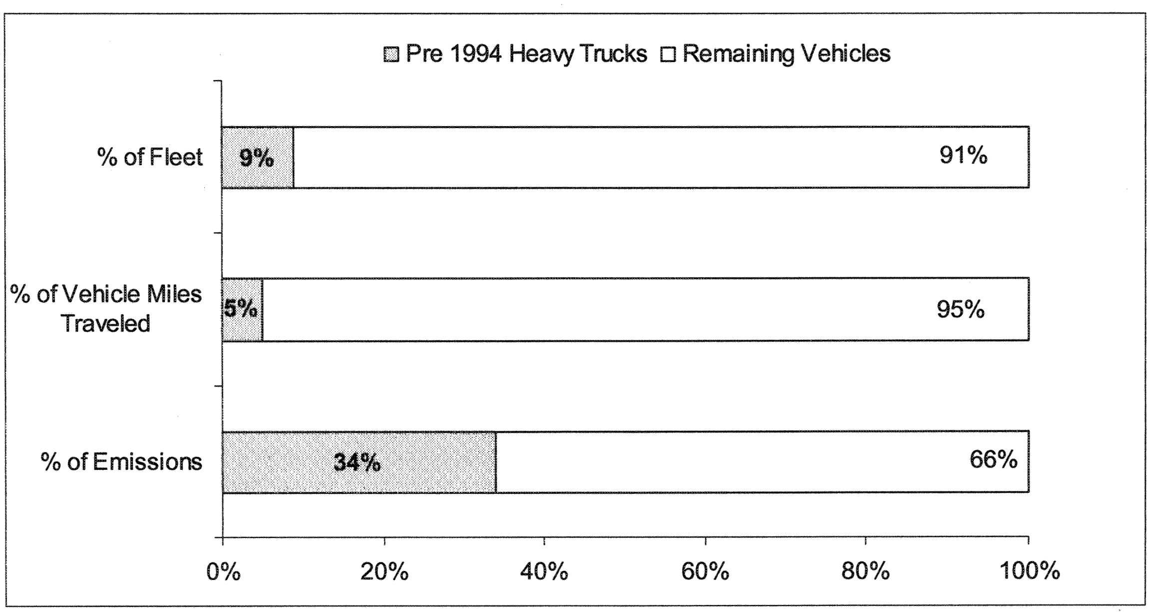
EXHIBIT 108: IMPACT OF PRE-1994 VEHICLES ON FLEET EMISSIONS IN FY 02



Source: OLO April, 2003

OLO also calculated the amount of pollution emitted by WSSC's pre-1994 heavy trucks. Exhibit 109 shows these 80 trucks account for 9% of the total fleet, 5% of the total mileage, and 34% of the total emissions. OLO believes that the pre-1994 heavy truck emissions are significant given the relatively small number of miles traveled by these vehicles.

EXHIBIT 109: IMPACT OF PRE-1994 HEAVY TRUCKS ON FLEET EMISSIONS IN FY 02

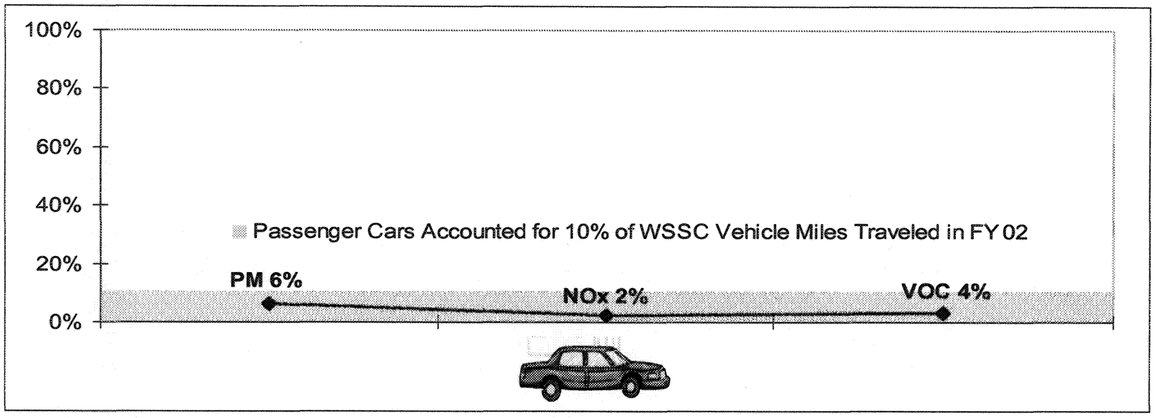


Source: OLO April, 2003

4. Emission Levels and Vehicle Miles Traveled by Vehicle Class

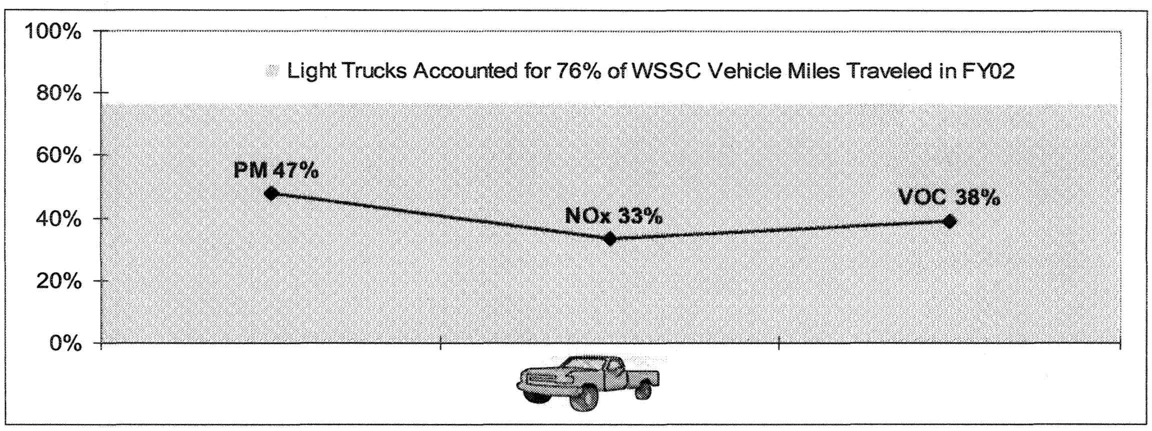
OLO examined the relationship between specific pollutants and vehicle miles traveled for each vehicle class. OLO found passenger cars and light trucks emit a disproportionately lower share of pollutants than heavy trucks. These results are summarized in the Exhibits 110, 111 and 112.

EXHIBIT 110: PASSENGER CARS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



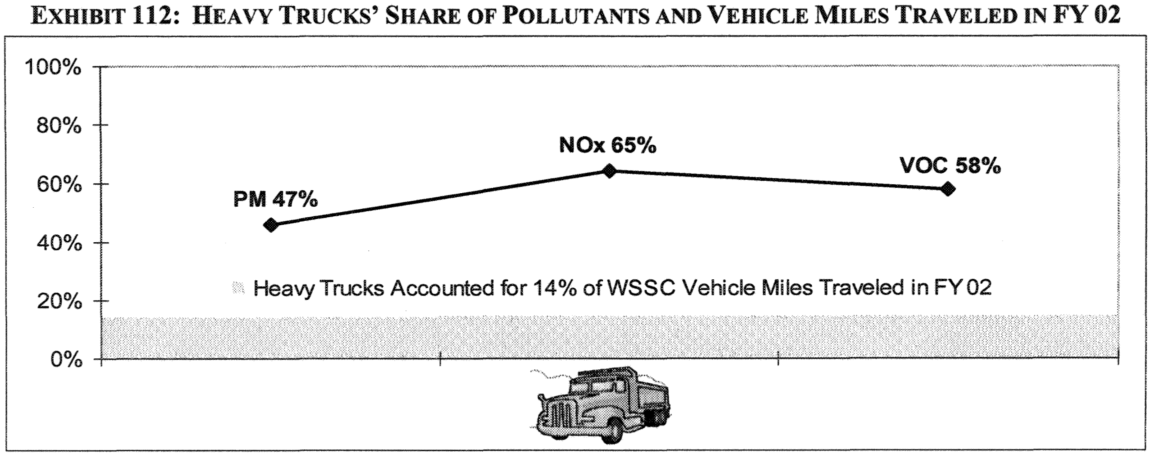
Source: OLO April, 2003

EXHIBIT 111: LIGHT TRUCKS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



Source: OLO April, 2003

EXHIBIT 112: HEAVY TRUCKS' SHARE OF POLLUTANTS AND VEHICLE MILES TRAVELED IN FY 02



Source: OLO April, 2003

EXHIBIT 113: COMPILATION OF COUNTY AND BI-COUNTY AGENCIES FLEET DATA

Agency	**Initial Dataset of FY 02 On-Road Vehicles Sent to OLO**	**# of FY 02 On-Road Vehicles**	**# of FY 02 Vehicles used to Calculate Emissions**	**Adjustments**		
				Agency[1]	OLO[2]	OLO[3]
MCG Transit Buses	431	337	322	Removed 94 buses which were no longer in service.	None	No emission factors for 2 diesel trolleys and 12 gasoline mini-buses.
MCPS School Buses	1,200	1,113	1,113	None	Removed 55 MY 02 and MY 03 buses. Removed 32 duplicate buses which had used more than one odometer.	None
MCG Cars and Trucks	2,721	2,553	2,484	Removed 73 heavy trucks which were no longer in service.	Removed 74 police vehicles "not yet placed in service," 21 Montgomery College vehicles, and 50 vehicles with no data.	No emission factors for 19 motorcycles.
MCPS Cars and Trucks	566	564	564	None	Removed two MY 03 vehicles.	None
WSSC Cars and Trucks	889	889	871	None	Removed 11 vehicles which had been retired and 7 vehicles with no data.	None
M-NCPPC Cars and Trucks	536	545	528	Added 18 "reserve fleet" vehicles and 3 additional vehicles.	None	No emission factors for 17 motorcycles.
MC Cars and Trucks	45	44	44	None	Removed one MY 03 vehicle.	None

[1] Adjustments to add or remove vehicles.
[2] Adjustments to establish consistent set of FY 02 vehicles and address incomplete data. Model year (MY).
[3] Adjustments to remove vehicles for which OLO did not identify emission factors.

Exhibit 114: Edwards and Kelcey Vehicle Emission Rates for NOX, NMHC and PM

(Reported in grams per mile)

Emission Rates for Nitrogen Oxide (NOX)							
Model Year	Pass Car	Lt Truck	HD Truck	Transit Bus-Diesel	Transit Bus - CNG	School Bus-Diesel	School Bus-CNG
1976	3.10	3.10	50.10	73.60		42.60	
1977	2.00	3.10	50.10	73.60		42.60	
1978	2.00	3.10	50.10	73.60		42.60	
1979	2.00	2.30	31.30	46.00		26.60	
1980	2.00	2.30	31.30	46.00		26.60	
1981	1.00	2.30	31.30	46.00		26.60	
1982	1.00	2.30	31.30	46.00		26.60	
1983	1.00	2.30	31.30	46.00		26.60	
1984	1.00	2.30	31.30	46.00		26.60	
1985	1.00	2.30	33.50	49.20		28.50	
1986	1.00	2.30	33.50	49.20		28.50	
1987	1.00	2.30	33.50	49.20		28.50	
1988	1.00	1.50	33.10	49.50		28.70	
1989	1.00	1.50	33.10	49.50		28.70	
1990	1.00	1.50	18.30	27.70	8.40	16.20	5.30
1991	1.00	1.50	15.00	23.20	8.40	13.80	5.30
1992	1.00	1.50	15.00	23.20	8.40	13.80	5.30
1993	1.00	1.50	15.00	23.20	8.40	13.80	5.30
1994	0.40	0.97	14.60	23.30	8.40	14.60	5.30
1995	0.40	0.97	14.60	23.30	8.40	14.60	5.30
1996	0.40	0.97	14.60	23.30	8.40	14.60	5.30
1997	0.40	0.97	14.60	23.30	8.40	14.60	5.30
1998	0.40	0.97	11.70	18.60	8.40	11.70	5.30
1999	0.40	0.97	11.70	18.60	8.40	11.70	5.30
2000	0.40	0.97	11.70	18.60	8.40	11.70	5.30
2001	0.40	0.97	11.70	18.60	8.40	11.70	5.30
2002	0.40	0.97	11.70	18.60	8.40	11.70	5.30
2003	0.40	0.97	6.70	10.70	8.40	6.70	5.30
2004	0.28	0.28	6.70	10.70	8.40	6.70	5.30
2005	0.21	0.21	6.70	10.70	8.40	6.70	5.30
2006	0.15	0.15	6.70	10.70	8.40	6.70	5.30
2007	0.09	0.09	3.20	5.60	5.60*	3.40	
2008	0.08	0.08	3.20	5.60	5.60*	3.40	
2009	0.07	0.07	3.20	5.60	5.60*	3.40	
2010			0.50	0.80	0.80*	0.50	

Emission Rates for Nonmethane Hydrocarbons							
Model Year	Pass Car	Lt Truck	HD Truck	Transit Bus-Diesel	Transit Bus - CNG	School Bus-Diesel	School Bus-CNG
1976	1.50	2.00	NA	NA		NA	
1977	1.50	2.00	NA	NA		NA	
1978	1.50	2.00	NA	NA		NA	
1979	1.50	1.70	4.70	6.90		4.00	
1980	0.41	1.70	4.70	6.90		4.00	
1981	0.41	1.70	4.70	6.90		4.00	
1982	0.41	1.70	4.70	6.90		4.00	
1983	0.41	1.70	4.70	6.90		4.00	
1984	0.41	0.90	4.70	6.90		4.00	
1985	0.41	0.90	4.10	6.00		3.50	
1986	0.41	0.90	4.10	6.00		3.50	
1987	0.41	0.90	4.10	6.00		3.50	
1988	0.41	0.90	4.00	6.00		3.50	
1989	0.41	0.90	4.00	6.00		3.50	
1990	0.41	0.90	4.00	6.00	1.90	3.50	1.20
1991	0.41	0.90	3.90	6.00	1.90	3.60	1.20
1992	0.41	0.90	3.90	6.00	1.90	3.60	1.20
1993	0.41	0.90	3.90	6.00	1.90	3.60	1.20
1994	0.25	0.41	3.80	6.10	1.90	3.80	1.20
1995	0.25	0.41	3.80	6.10	1.90	3.80	1.20
1996	0.25	0.41	3.80	6.10	1.90	3.80	1.20
1997	0.25	0.41	3.80	6.10	1.90	3.80	1.20
1998	0.25	0.41	3.80	6.10	1.90	3.80	1.20
1999	0.25	0.41	3.80	6.10	1.90	3.80	1.20
2000	0.25	0.41	3.80	6.10	1.90	3.80	1.20
2001	0.25	0.41	3.80	6.10	1.90	3.80	1.20
2002	0.25	0.41	3.80	6.10	1.90	3.80	1.20
2003	0.25	0.41	1.50	2.30	1.90	1.50	1.20
2004	0.11	0.11	1.50	2.30	1.90	1.50	
2005	0.11	0.11	1.50	2.30	1.90	1.50	
2006	0.10	0.10	1.50	2.30	1.90	1.50	
2007	0.09	0.09	0.40	0.60	0.60*	0.40	
2008	0.08	0.08	0.40	0.60	0.60*	0.40	
2009	0.07	0.07	0.40	0.60	0.60*	0.40	
2010			0.40	0.60	0.60*	0.40	

Emission Rates for Particulate Matter							
Model Year	Pass Car	Lt Truck	HD Truck	Transit Bus-Diesel	Transit Bus - CNG	School Bus-Diesel	School Bus-CNG
1976	No Std	No Std	NA	NA		NA	
1977	No Std	No Std	NA	NA		NA	
1978	No Std	No Std	NA	NA		NA	
1979	No Std	No Std	NA	NA		NA	
1980	No Std	No Std	NA	NA		NA	
1981	0.60	0.60	NA	NA		NA	
1982	0.60	0.60	NA	NA		NA	
1983	0.60	0.60	NA	NA		NA	
1984	0.60	0.60	NA	NA		NA	
1985	0.60	0.60	NA	NA		NA	
1986	0.60	0.60	NA	NA		NA	
1987	0.60	0.60	NA	NA		NA	
1988	0.20	0.26	1.90	2.80		1.60	
1989	0.20	0.26	1.90	2.80		1.60	
1990	0.20	0.26	1.80	2.80		1.60	
1991	0.20	0.26	0.80	1.20		0.70	
1992	0.20	0.26	0.80	1.20		0.70	
1993	0.20	0.26	0.80	1.20		0.70	
1994	0.08	0.10	0.30	0.50		0.30	
1995	0.08	0.10	0.30	0.50		0.30	
1996	0.08	0.10	0.30	0.50		0.30	
1997	0.08	0.10	0.30	0.50		0.30	
1998	0.08	0.10	0.30	0.50		0.30	
1999	0.08	0.10	0.30	0.50		0.30	
2000	0.08	0.10	0.30	0.50		0.30	
2001	0.08	0.10	0.30	0.50		0.30	
2002	0.08	0.10	0.30	0.50		0.30	
2003	0.08	0.10	0.30	0.50	0.05	0.30	0.03
2004			0.30	0.50	0.05	0.30	0.03
2005			0.30	0.50	0.05	0.30	0.03
2006			0.30	0.50	0.05	0.30	0.03
2007			0.03	0.05	0.05*	0.03	
2008			0.03	0.05	0.05*	0.03	
2009			0.03	0.05	0.05*	0.03	
2010			0.03	0.05	0.05*	0.03	

*Through discussions with DEP and Edwards and Kelcey OLO adjusted the CNG rates to reflect that CNG transit bus emission rates will at least be comparable to diesel bus rates in 2007 and beyond.

For E-85 vehicles, OLO reduced NOX emissions by 10%, NMHC emissions by 15% and PM emissions by 20% based on EPA Fact Sheet EPA420-F-00-05 at www.epa.gov

For CNG vehicles, OLO reduced NOX emissions by 35 to 60%, NMHC emissions by 50 to 75% and PM by 0% based on EPA Fact Sheet EPA420-F-00-033 at www.epa.gov

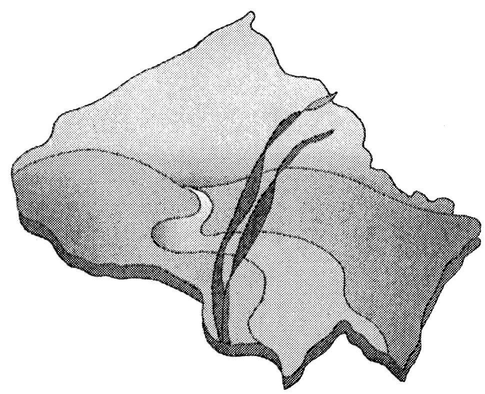
Source: Edwards and Kelcey, Inc., MCDEP, OLO, 2003

Exhibit B

Summer 2003 Ozone Action Day Communication Protocol

For Montgomery County Agencies

Department of Environmental Protection



Montgomery County Maryland

For Implementation With a Code Red Forecast

Introduction

Ozone is an odorless, colorless gas that forms in the atmosphere. Ozone occurs both in the Earth's upper atmosphere and here at ground level. Ozone can be good or bad, depending on where it is found. Ozone occurs naturally in the earth's upper atmosphere, 10 to 30 miles above the earth's surface, where it shields us from the sun's harmful ultraviolet rays ("good ozone"). However, here at ground-level "bad ozone" is an air pollutant that damages human health, vegetation, and many common materials and is the key ingredient of urban smog.

At ground-level, ozone is not emitted directly into the air, but is created by a chemical reaction between oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. Motor vehicle exhaust, fumes from lawnmowers, emissions from power plants and industrial facilities, gasoline vapors, and chemical solvents are some of the major sources of NOx and VOCs, also known as ozone precursors. Repeated exposure to ground-level ozone pollution may cause permanent damage to the lungs and trigger a variety of health problems including chest pains, coughing, nausea, throat irritation, and congestion. It can also worsen bronchitis, heart disease, emphysema, and asthma, and reduce lung capacity. Because of the environmental and health effects of ground-level ozone, ozone is one of six criteria air pollutants that the EPA has set standards. Areas that do not meet the EPA set standards for a criteria pollutant are called nonattainment areas. Montgomery County is part of the Washington Metropolitan Non-Attainment area for Ozone.

In an effort to reduce ozone pollution, Montgomery County has established an Ozone Action Day Plan to reduce the emittance of ozone precursors during a code-red forecast day. When ground-level ozone in the Washington area is forecast to be code red, the County will be taking voluntary actions to reduce emissions of smog-forming chemicals and to provide notice of the forecast to its employees and residents. These actions are intended to encourage employees, other governments, and businesses to voluntarily reduce emissions. Employees and residents who are most at risk from exposure to ground-level ozone (asthmatics and people with other medical conditions, children, pregnant women, outdoor workers and others engaged in strenuous activity, and the elderly) can then plan to take precautions to protect themselves such as limiting outdoor activity.

This protocol establishes the notification system to ensure that all participating County agencies are notified when a code red day is forecast for the following day. The Department of Environmental Protection (DEP) will activate this protocol when a code red day is forecast. Those individuals and agencies are then responsible to carry out the actions outlined in this Ozone Action Day protocol.

Forecast Procedures

A team of meteorologists and scientists produce ozone forecasts for the Washington Metropolitan area for the next day usually by 3:00 pm. Because ground-level ozone forms in the presence of heat and sunlight, the weather forecast in the summer season plays a vital role in predicting the ground-level ozone levels for the following day. The Washington area forecast applies to the entire region including Montgomery County. This forecast is communicated to the Washington Area Council of Governments (COG) who in turn notifies the Ozone Action Day participants, other organizations, the news media, and the public in the event of a code red forecast for the following day. The chart below describes the color code forecast system used.

Category	Descriptor	Ozone Level
Code Green	Good	0-50 ppb
Code Yellow	Moderate	51-100 ppb
Code Orange	Unhealthy for Sensitive Groups	101-150 ppb
Code Red	Unhealthy	151+ ppb

COG uses three means of communication: a recording on a telephone line, a posting on the COG website, and a fax (only for code red forecasts) to requesting organizations. On all days, COG will place a 3:30 pm recording on its phone line and post the next day's forecast on its website.

DEP staff will check either the COG telephone line at 202.962.3299 or the COG website at www.mwcog.org/dep/air/airqual.html daily to obtain the next day's forecast. DEP staff will then place the next day's forecast on DEP's ozone action day hotline so that any citizen may call DEP's ozone action day hotline at 240.777.7777 and obtain the next day's forecast. This is accomplished by:

1. Dial 71010; ext. 77777
2. Password: DEPOAD (337623)
3. Press 4, then 6 to change greeting. Hi, this is Montgomery County Department of Environmental Protection's Ozone Action Day Hotline. The Air Quality forecast for (date) is code (color forecast). Press # to end recording.
4. Press 99 to exit.
5. After obtaining the forecast, DEP staff will also email the next day's forecast to Joe Keyser at joe@askdep.com and Shelly Janashek at shelly@askdep.com so that this information can be placed on DEP's website, askdep.com; providing another vehicle for the citizens to use to obtain ozone forecast information.

Additionally, should the forecast be code red, DEP will contact the organizations listed below via email so that they can initiate their ozone action day procedures. (Attachment I contains sample email). Additionally, DEP will email ITHELP and Dieter Klinger at ITHELP@co.mo.md.us , Dieter.Klinger@co.mo.md.us to initiate a general distribution email to all county employees. Shelly Janashek is the designated individual to initiate a bulletin on the county intranet site. This should encourage everyone to take voluntary actions to reduce ozone precursor emissions. (Attachment II contains a sample general distribution email which needs to be copied and pasted on their emails).

CODE RED EMAIL DISTRIBUTION LIST

James Caldwell	DEP	240.777.7700	240.777.7765	caldwj@co.mo.md.us	Initiate protocol
Mary Richmond	DEP	240.777.7758	240.777.7752	mary@askdep.com	Initiate protocol
Joe LaDana Dan Locke	RRF	240.777.6439	301.349.5309	Joe.LaDana@co.mo.md.us Dan.Locke@co.mo.md.us	RRF curtailment to 70% when power grid permits.
Ramano Rao	Solid Waste	240.777.6438	240.777.2681	DPWT-SWS.RAOR@co.mo.md.us Bcrispell@CovantaEnergy.com Tvelez@CovantaEnergy.com DLaPorte@CovantaEnergy.com DLeone@CovantaEnergy.com DDonohoo@CovantaEnergy.com TWerni@CovantaEnergy.com DProuty@CovantaEnergy.com MThorsen@CovantaEnergy.com TZimmerman@CovantaEnergy.com RMoyer@CovantaEnergy.com MFreedman@CovantaEnergy.com GregMullen@CovantaEnergy.com SJenness@CovantaEnergy.com	RRF curtailment to 70% when power grid permits.
Emil Wolanin	Traffic & Parking	240.777.8788	240.777.2080	DPWT-TP.WOLANE@co.mo.md.us	Radio and Highway message coordination and center line paint striping curtailment.
John Riehl or Bill Corder	DPW&T Transportation Management Center	240.777.2100	240.777.8505	DPWT-TP.CORDEB@co.mo.md.us DPWT-TP.RiehlJ@co.mo.md.us	Radio and highway message coordination.
Jim Rhoderick Richard Boylan Tony Ricchiuti	DPWT Sign Shop DPWT Traffic	301.279.1870 301.279.1870 240.777.2637	301.279.1996 301.279.1996 240.777.2637	DPWT-TP.RHODEJ@co.mo.md.us Richard.boylan@co.mo.md.us DPWT-TP.RICCHT@co.mo.md.us	Center line paint striping curtailment.

Andrea Bush	DPWT Transit	240.777.5805	240.777.5801	DPWT-TRN.BUSHA@co.mo.md.us jonesc@co.mo.md.us lemasb@co.mo.md.us curtil@co.mo.md.us cadem@co.mo.md.us castrj@co.mo.md.us hugheja@co.mo.md.us robinbr@co.mo.md.us sweenr@co.mo.md.us Philip.McLaughlin@co.mo.md.us Betty.Peake@co.mo.md.us	Code red ride free
Alfie Steele	DPWT Transit-Central Dispatch	240.777.5840	240.777.5841	alfie.steele@co.mo.md.us plumme@co.mo.md.us Silveh@co.mo.md.us thompke@co.mo.md.us managr@co.mo.md.us huntt@co.mo.md.us keithr@co.mo.md.us bucklp@co.mo.md.us Bynumr@co.mo.md.us	Code red ride free; Instant carpool/ vanpool for employees.
Al Roshdieh	Facilities& Services	240.777.6008	240.777.6077	al.roshdieh@co.mo.md.us	County property lawn mowing reductions.
Wayne Nebel	Facilities & Services	240.777.6008	240.777.6077	dpwt-fs.nebelw@co.mo.md.us	County property lawn mowing reductions
John Thompson	Highway Services	240.777.7600	240.777.7670	DPWT-HWY.THOMJ@co.mo.md.us	Curtailment of median strip herbicide application and mowing; Asphalt paving curtailment.
Tom Orr	Highway Services	240.777.7601	240.777.7670	tom.orr@co.mo.md.us	Curtailment of median strip herbicide application and mowing; Asphalt paving curtailment.
Aubrey Bentham	Fleet Management	240.777.5773	240.777.4742	DPWT-FMS.BENTHA@co.mo.md.us	County fleet refueling after 7:00 pm. Signs at 8 refueling stations.

Summary

Ozone control receives a substantial amount of DEP's attention because of the non-attainment patterns in the County and the health and environmental effects of ozone. Since ozone is one pollution problem driven by individuals, as much as industry, Montgomery County must take a leadership role, by stepping forward and setting an example to reduce its ozone precursor emissions. Part of DEP's initiative includes public education and outreach so that all citizens in Montgomery County may do their share, to be part of the solution.

Exhibit B

Attachment I

CODE RED FORECAST

Date: 05/03/2001

To: All Ozone Action Day Participants

From: Mary C. Richmond, Air Quality Specialist

A CODE RED OZONE FORECAST HAS BEEN ISSUED FOR TOMORROW. PLEASE ACTIVATE YOUR OZONE ACTION DAY PROCEDURES.

THIS FORECAST IS FOR THE METROPOLITAN, D.C. AREA, INCLUDING MONTGOMERY COUNTY.

Attachment II

Code Red Ozone Action Day Alert is Scheduled for Tomorrow!

HELP BE PART OF THE SOLUTION--HERE'S WHAT YOU CAN DO!!

- ☐ Carpool, telecommute, or take mass transit to get to work (tomorrow is a ride free day in Montgomery County).
- ☐ Defer driving, or if you must, combine trips and refuel after dark.
- ☐ Postpone lawn and garden chores that use gasoline powered equipment.
- ☐ Wait for a cooler day to use oil-based paints (better yet, switch to non-voc paints).
- ☐ Postpone using aerosols and household products that contain solvents (even better, switch to non-aerosol products and products that do not contain solvents).
- ☐ Brown bag your lunch so that you are not running your car at noon.

DID YOU KNOW??

- ☐ On Ozone Action Days, for every one that does not mow their lawn, we reduce VOCs by an amount equivalent to driving a car from Baltimore to Hartford Connecticut.
- ☐ Every summer day, gas-powered lawn and garden equipment releases more than 100 times the VOCs of a typical large industrial plant.

Ozone is an odorless, colorless gas that forms in the atmosphere. Ground-level ozone is an air pollutant that damages human health, vegetation, and many common materials and is the key ingredient of urban smog. Repeated exposure to ground-level ozone may cause permanent damage to the lungs. Inhaling ozone may trigger a variety of health problems including chest pains, coughing, nausea, throat irritation, and congestion. It can also worsen bronchitis, heart disease, emphysema, and asthma, and reduce lung capacity. Those at risk from exposure to ground-level ozone, asthmatics and people with other medical conditions, children, outdoor workers and the elderly, should limit their outdoor activities tomorrow.

Ground level ozone is caused when strong sunlight reacts with pollutants from a variety of sources- such as the fumes from our vehicles, lawn-mowers, and boats, or emissions from power plants and industrial facilities. The main ozone-causing pollutants are volatile organic compounds (VOCs) and nitrogen oxides (NOx). This is one pollution problem driven by individuals, as much as industry. Our cars account for 30-40% of pollutants that cause Ozone in the Baltimore/Washington area.

FOR MORE INFORMATION VISIT DEP'S WEBSITE: ASKDEP.COM. Contact person, Mary Richmond, DEP, 240.777.7758.

STANDARD PROCEDURES
OF THE
WASHINGTON SUBURBAN SANITARY COMMISSION

ORIGINATOR & POSITION	SP NUMBER	APPROVE BY/DATE	EFFECTIVE DATE	PAGE 1
Mohammad T. Habibian Environmental Group Leader M. T. Habibian 4/19/02	ENG 02-01 SUPERSEDES N/A	John R. Griffin General Manager John R. Griffin 4/19/02	April 19, 2002	OF 6

SUBJECT: CLEAN AIR POLICY

I. **PURPOSE** – To provide flexibility in the operational procedures of the Commission to allow and encourage managers and employees to take actions that help improve air quality and reduce ground-level ozone, as well as limiting personal exposure to poor air quality during Code Red Ozone Action Days.

II. **BACKGROUND** – Ground-level ozone is created by reactions of sunlight with volatile organic compounds (e.g., fuel products, aerosol propellants, paint volatiles) and nitrogen oxides (e.g., vehicle emissions) in hot stagnant air, leading to smog-like conditions. The frequency of Code Red days is not high. For perspective, Montgomery and Prince George's Counties experienced less than 3 Code Red days per year on average (1992-2001), although 10 Code Red forecasts were issued in 2001

However, the health impacts can be significant, especially on sensitive people, and hospitals have reported overload on such days. High concentrations of ground-level ozone on Code Red days present a significant health hazard to outdoor workers, young children and people with respiratory problems. Health professionals advise limiting the exposure of outdoor workers to such conditions.

Limiting vehicle emissions and releases of volatile organic compounds to the air on forecast Code Red days can have a big impact by helping to reduce the formation of ground-level ozone. Changing vehicle use habits can also help reduce fuel consumption, save money, and contribute to improved air quality at all times.

The Commission is a member of the Clean Air Partners, a regional consortium of Maryland, Washington, D.C. and northern Virginia businesses, government agencies, and health advocacy organizations. The Commission is also a registered participant in the Clean Air Partners' Ozone Action Days program.

III. **POLICY** – The Commission encourages and supports measures that protect the health of the greater community, including members of our families who may experience breathing problems (e.g., chronic asthma). Specific measures that Commission managers and employees can take to reduce emissions are described in IV below. The Commission encourages all employees to limit their outdoor activities on Code Red days, and allows employees with respiratory conditions that prohibit working in a high ozone concentration environment and who cannot be reassigned to work in a climate-controlled facility to limit their exposure by taking sick leave, as described in V below. The Environmental Group provides advance notification of Code Red days and educational/awareness materials, as described in VI and VII below. Current Standard Procedures should be modified by the respective originating organizations to reflect the provisions of this policy

IV. ACTIONS TO REDUCE OZONE-CAUSING EMISSIONS

A. Clean Air Actions that are Applicable Only on Code Red Ozone Action Days

The following actions apply to the Commission's in-house work practices. Where applicable, future contracts should also address these provisions.

1. Modified Time of Day for Fleet Vehicle Refueling

Whenever possible, fleet vehicle refueling will be restricted to the early morning departure period, rather than the customary mid-afternoon return period.

This policy will be implemented through specific operating procedures promulgated by the Fleet Services and Customer Care Groups. Fuel dispensers may be posted as unavailable during a certain period of the day.

2. Lawn Care and Groundskeeping

Commission employees (and contractors, if so obligated by their contracts) will not use gasoline powered mowers, trimmers, or other similar lawn care and groundskeeping equipment on forecast Code Red Ozone Action Days. Alternative work activities, or use of electric powered equipment, are encouraged.

3. Painting and Maintenance

Commission employees (and contractors, if so obligated by their contracts) will not perform any outdoor painting or outdoor cleaning of facilities with solvents containing volatile compounds on Code Red Ozone Action Days.

B. Clean Air Actions that are Applicable at All Times

The following actions apply at all times, including on forecast Code Red Ozone Action Days, because of the environmental benefit of reducing tailpipe and fuel vapor emissions overall, because of associated savings in fuel costs, and because of greater efficiency and saving of labor time. Implementing these actions throughout the year ensures necessary changes in our habits and facilitates observance of Code Red provisions.

1. Limit Vehicle Idling Time

Operators of Commission motor vehicles and motorized equipment are required, whenever possible, to turn off motors, which routinely are left idling for long periods when the vehicles are not being driven or the equipment is not being actively used.

This policy applies to the Commission's fleet of over 800 motor vehicles, as well as hundreds of other pieces of stationary motorized equipment. The policy will be implemented through specific operating procedures promulgated by the Fleet Services and Customer Care Groups.

2. Less Frequent Vehicle Refueling

Drivers of Commission fleet vehicle are required, whenever possible, to refuel only when the fuel gauge drops below one-half, rather than after returning from every trip. This will significantly reduce the frequency of refueling, while still maintaining vehicles in a state of sufficient readiness for reasonable local travel.

This policy will be implemented through specific operating procedures promulgated by the Fleet Services and Customer Care Groups.

C. Additional Voluntary Actions That Can be Taken by Employees

The Commission encourages all employees to take voluntary actions, to the extent possible, to minimize the release of volatile organic compounds and nitrogen oxides to the air on Code Red days. Employees will be reminded and encouraged to follow these specific actions via email or bulletin board notices when Code Red days are expected.

1. Carpool

Employees are encouraged to form carpools for routine commuting to work, as well as specifically on forecast Code Red days. Carpooling can help reduce regional traffic congestion, save fuel resources, and contribute to improved air quality overall through reduced tailpipe emissions.

2. Use Public Transit

Employees living near public transit routes that serve Commission facilities are encouraged to use public transit services on forecast Code Red days. Many public transit services offer free rides on Code Red Ozone Action Days as an incentive.

3. Combine Errands by Vehicle

Employees are encouraged to limit the number of non-essential trips by vehicle on forecast Code Red days. The Commission urges employees to consider putting off non-urgent shopping or similar personal errands during lunch hours, and to combine errands to the extent possible.

4. Refuel Personal Vehicle After Dusk

Refueling personal vehicles after dusk on forecast Code Red days limits the amount of fuel vapor that would otherwise be released to the air during the hotter part of the day. Volatile hydrocarbons quickly disperse and do not react to form ozone in the absence of direct sunlight.

5. Postpone Home Lawn Mowing

Employees are encouraged to put off until a cooler day any lawn mowing and similar home yard work involving gasoline powered equipment (e.g., trimmers) on forecast Code Red days.

6. Limit Painting and Cleaning

Employees are encouraged to limit their use of painting, cleaning and aerosol products containing volatile organic compounds used as propellants, solvents or carriers. The Commission encourages use of substitute products at all times that do not contain substances associated with upper atmosphere ozone depletion.

D. Carpool and Public Transit Incentives to Reduce Vehicle Use

Routine public transit users and routine carpoolers will be recognized for their significant contribution to fuel savings and reduced emissions with a Clean Air Award on Earth Day/similar events. To qualify, transit users and carpool participants must register with the Environmental Group through their supervisor or Group Leader.

NOTE: Employees who carpool routinely may be eligible for reduced automobile insurance rates. Employees should contact their own insurance carrier or insurance agent to determine their eligibility. Employees who carpool routinely at least two days per week are encouraged to register with the Washington area Commuter Connections Guaranteed Ride Home (GRH) program (1-800-745-RIDE) or www.mwcog.org/commuter/Bdy-GRH.html.

V. ACTIONS TO REDUCE EXPOSURE TO UNHEALTHY AIR QUALITY

A. Unscheduled Leave

An employee who has a respiratory condition that prohibits working in a Code Red Ozone environment and who cannot be reassigned to work in a climate-controlled facility may take sick leave on forecast Code Red Ozone Action Days without being charged an occurrence of unscheduled absence. The employee is required to submit to the supervisor or have on file documentation from a physician that the condition prohibits working in a high ozone concentration in outside air.

The Commission will open on time and will not close early during forecast Code Red Ozone Action Days.

B. Modified Work Activities

Personnel who normally work outdoors may receive alternative assignments on forecast Code Red Ozone Action Days. Modification of outdoor work activities will be at the discretion of employees' supervisors and Group Leaders.

C. Limit Strenuous Outdoor Activity

Employees are encouraged to put off strenuous outdoor exercise (e.g., jogging, cycling and similar aerobic activities) on forecast Code Red Ozone Action Days. Employees may join the Fitness Center, which offers a climate-controlled environment for exercise year-round.

D. Day Care at Consolidated Office Building

Outdoor playtime will not be offered at the Day Care facility on forecast Code Red Ozone Action Days. Substitute indoor activities will be offered to children at the Day Care facility.

VI. ADVISORY OF CODE RED AIR QUALITY FORECAST

A. Notification of Code Red Forecast

The Commission's Environmental Group is the designated point of contact to receive advance notification of the forecast from the Ozone Action Days program. This advance notice is received on the afternoon of the day preceding the Code Red forecast. An Environmental Group staff member or designated alternate is responsible for promulgating the Code Red advisory within the Commission.

B. Communication of Code Red Forecast

1. A Commission-wide e-mail notice will be issued on the preceding day to alert employees of the forecast.

2. The Radio Room, Control Center and/or Employee hotline (206-PIPE) will broadcast the announcement.

3. The daily forecast air quality, including any imminent or actual Code Red condition, will be posted on the Commission's Intranet during the hot weather season (typically May to September).

4. Supervisors and their administrative assistants at the main Commission facilities (i.e., service centers/depots, treatment plants, and office buildings) will be contacted additionally on the preceding day by e-mail notice. This notice may include a request to post an alert sign and advise employees who do not have access to e-mail. Customer Care Unit Coordinators may be delegated to notify their personnel orally or by other means.

   The facility supervisors will be responsible for arranging for Code Red alert signs to be posted at the entrance gates of their respective facilities. These signs are to alert incoming or outgoing employees of the Code Red forecast, including personnel who may have concluded their shifts and left the premises before the forecast was received.

   An Ozone Action Day flag, provided by the Clean Air Partners organization, will be flown at the Consolidated Office Building (COB) on the forecast Code Red day(s).

VII. EMPLOYEE AWARENESS OF AIR QUALITY

A. Distribution of Educational and Promotional Written Materials

1. Periodic announcements or notices will be placed as paycheck inserts. The notices may include summaries of the new Commission Ozone Action Days policy, specific elements of the new policy initiatives, or annual reminders in the Spring prior to onset of hot weather conditions.

2. Clean Air Partners brochures will be distributed at key locations for employees and visitors to take (e.g., COB Lobby and Lake Level parking garage entrances, Office of Communications, Service Center lobbies and lunchrooms, treatment plant lunchrooms).

3. Clean Air Partners posters (e.g., Ozone Action Days scale from Code Green to Code Red) will be posted on notice boards or at key locations.

B. Awareness of Air Quality

An air quality message will be added to the Commission Intranet, adjacent to the existing weather forecast.

Distribution List:

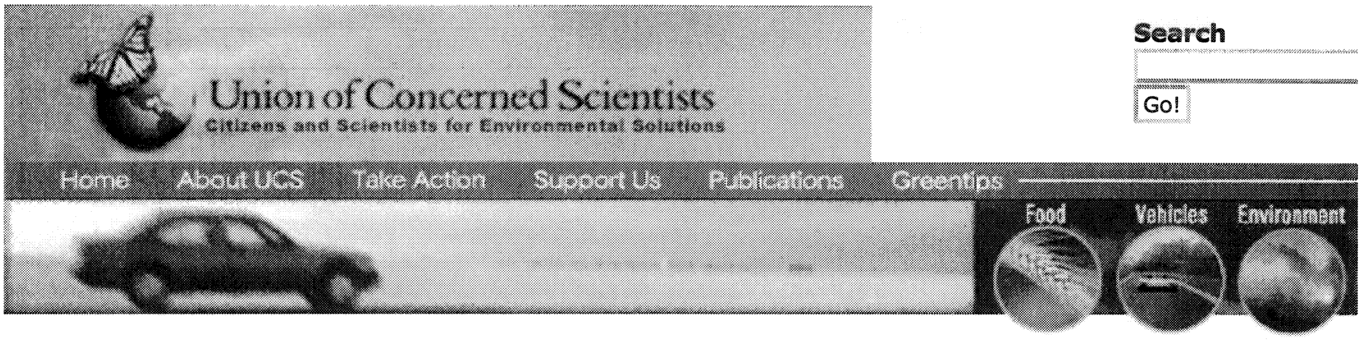
MASTER VOLUME LIST:

General Manager's Office
Internal Audit Office
Secretary's Office
Human Resources Group

OTHER DISTRIBUTION:

Office of Communications
Office of General Counsel
Office of Intergovernmental Relations
Customer Care Team
Engineering and Construction Team
Entrepreneurial Team
Information Technology Team
Mission Support Team
Production Team
Rate Stabilization and Debt Reduction Team
All Group Leaders

Exhibit D

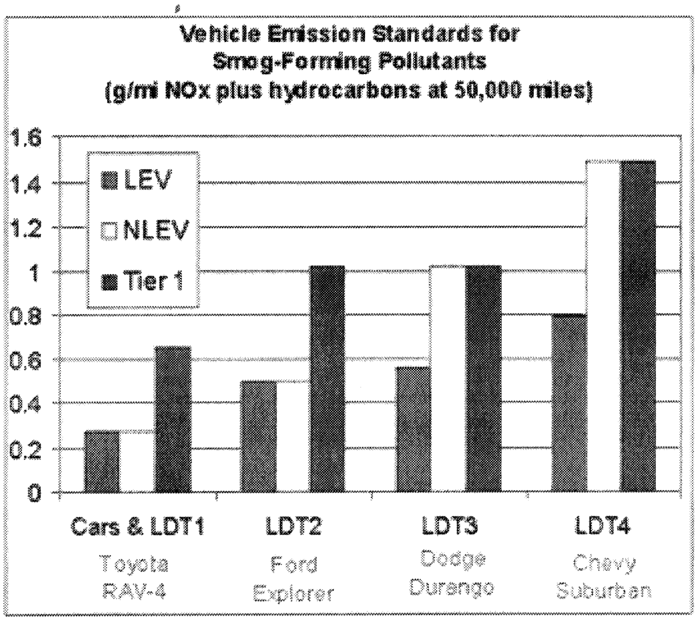


Clean Vehicles

backgrounder
The Plain English Guide to Tailpipe Standards

The federal Clean Air Act (CAA) provides the framework for regulating emissions from motor vehicles. In 1970, it established nationwide air quality standards to protect public health. Recognizing the large contribution motor vehicles make to air pollution, the Clean Air Act also set the first federal tailpipe standards. Finally, the CAA granted California, which has some of the worst air quality in the nation, the authority to set it's own vehicle emission standards. As of 1990, other states may adopt the California program as their own (and several have done so), but are otherwise prohibited from setting their own emission standards.

Vehicle emission standards have successfully reduced pollution from cars and trucks by about 90 percent since the 1970s. But Americans are driving more miles each year, partially offsetting the environmental benefits of individual vehicle emissions reductions. That's why even tougher emission standards for conventional vehicles, and zero and near-zero emissions vehicles are essential for achieving and maintaining clean air.



What pollutants and vehicles are regulated?

In this Section

Program Overview
Advanced Vehicles
Cars and SUVs
Trucks and Buses
Health and Environment
Archive

Contents

Updates
- Diesel Rule Keeps on Trucking
- Clean Buses for California
- Clean Buses for Boston

FAQs
- Alternative Fuel School Buses

Analysis
- Rolling Smokestacks: Cleaning and Buses

Campaigns
- Updating School Buses: Cleane

Backgrounders
- Clean School Buses, Healthy K
- Going to School May be Hazarc
- Cleaner Transit -- New Buses
- The Plain English Guide to Tail|

Guides
- Cleaner School Buses: What Yc

©D-42

Exhibit D

Federal and California tailpipe standards limit exhaust emissions of five pollutants: hydrocarbons (HC), nitrogen oxides (NO_X), carbon monoxide (CO), particulate matter (PM, for diesel vehicles only), and formaldehyde (HCHO). Hydrocarbons and NO_X are the major contributors to urban smog.

The standards regulate emissions from cars and "light-duty trucks," which includes sport utility vehicles (SUVs), pickups, and minivans. Currently, light trucks are allowed to emit up to five and a half times more smog-forming pollution than cars.

Federal Standards (Tier 1, Tier 2, and NLEV)

Tier 1 refers to the current federal tailpipe standards for passenger cars and light trucks. Under this program there is one emission category (called the Tier 1 category), but SUVs, minivans, pickup trucks, and diesel vehicles are allowed to pollute more than gasoline cars.

Tier 2. Tier 2 is a fleet averaging program, modeled after the California LEV II standards. Manufacturers can produce vehicles with emissions ranging from relatively dirty to zero, but the mix of vehicles a manufacturer sells each year must have average NO_X emissions below a specified value. This provides automakers with flexibility for meeting the standards and is a cost-effective method of reducing overall pollution from automobiles.

The Tier 2 program will cut vehicle pollution significantly, but UCS is working to strengthen several aspects of the program. Find out what you can do to help on our Tier 2 campaign page.

NLEV stands for "National Low-Emission Vehicle Program." It is the same as the California LEV program (see below), with two notable differences.

- NLEV reduces emissions from cars and the lightest trucks, but the standards for bigger SUVs and pickup trucks remained unchanged.
- NLEV does not include a zero-emission vehicle sales requirement.

California Standards (LEV and LEV II)

The LEV and LEV II programs are both fleet average programs, much like the new federal Tier 2 standards (see above), but are programs are based on a fleet hydrocarbon, rather than NO_X, standard. Manufacturers can certify vehicles to one of several emissions categories as long as the average hydrocarbon emissions of all new vehicles sold meets a specified standard. This standard becomes more stringent each year, forcing manufacturers to move toward a cleaner overall mix of vehicles.

©D-43

Exhibit D

TAILPIPE TIMELINE	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Federal	Tier 1 [1]			Tier 1 and NLEV			Tier 2 phase-in						Tier 2	
California	LEV						LEV II phase-in			LEV II				
States opting into California's LEV program [2]	NY NA		NY MA VT	NY, MA, VT, ME			MA, ?? other states may choos to adopt the LEV II program [2]							

1. The NLEV program began in 1999 in the following states: Connecticut, New Hampshire, New Jersey, Pennsylvania, Rhode Island, Washington DC, Delaware, Maryland, and Virginia
2. The Clean Air Act allows states to adopt the California Low Emission Vehicle Program.

The LEV programs also include a 10 percent zero-emission vehicle (ZEV) production requirement, starting in 2003. Under the LEV II program, some hybrid electric, extremely low-emission gasoline and methanol fuel-cell vehicles can qualify for "partial ZEV" credits. Partial credits are given based on several criteria, including low emissions associated with refining and distribution of the fuel, the all-electric vehicle range (for hybrids), and near-zero evaporative and tailpipe emissions.

LEV: Under the LEV program, vehicles may certify to one of the following emission categories:

TLEV = Transitional Low-Emission Vehicle
LEV = Low-Emission Vehicle
ULEV = Ultra Low-Emission Vehicle
ZEV = Zero-Emission Vehicle

A note on emissions categories: all LEVs are not alike.

While light trucks and cars can all certify as "LEVs", the numerical standards are actually different between the two types of vehicles. As a result, a LEV truck (such as an SUV) is not as clean as a LEV car; it can emit up to three times more smog-forming pollution. This difference will be eliminated under LEV II.

LEV II: Under the LEV II program, vehicles may certify to one of the following emission categories:

LEV = Low-Emission Vehicle
ULEV = Ultra Low-Emission Vehicle
SULEV = Super Ultra Low-Emission Vehicle
ZEV = Zero-Emission Vehicle

Although the category names are virtually the same names as under the LEV program, the actual standards are much more stringent and emissions loopholes for light trucks are eliminated.

Tailpipe Tables

Craving more detailed information? The following pdf files include the nitty-gritty details -- everything you ever wanted to know about passenger vehicles but were afraid to ask.

©D-44

Exhibit D

- Phase-in Schedules
  Phase-in schedules for LEV II and Tier 2. Includes the Tier 2 fleet NO_X requirements and fleet NMOG requirements under LEV and LEV II.

- Table of Federal and California Light Truck Designations

Performance Comparison of Alternative Fuels and Vehicle Technologies

Alternative Fuel	Environmental Performance	Vehicle Performance
Ethanol	• E-10 and E-85 produce less carbon monoxide than gasoline E-10 production of ozone is similar to gasoline • E-85 production of air toxics is similar to gasoline. • Ethanol generates low levels of particulate matter compared to diesel fuel. • Biomass ethanol levels of greenhouse gas emissions can be lower…than gasoline??.	• E10 and E85 have vehicle performance comparable to gasoline. • Range of E85 flex fuel vehicles is reduced when operating on E85 compared to gasoline.
Natural Gas	• Lower reactive hydrocarbon emissions compared to gasoline • Low carbon monoxide compared to gasoline. • Lower greenhouse gas emissions compared to gasoline. • Particulate matter and air toxic emissions very low compared to gasoline and diesel.	• Range is 50% of gasoline vehicles; can add storage tanks to increase range. • Converted vehicles may experience small power loss. • Engine efficiency may be increased if designed to use higher octane of natural gas.
Hybrid Gasoline/Electric Vehicles	• Reduced emissions operating in electric mode.	• Hybrid gasoline engines are rated as ultra low emission vehicles (ULEV) • Efficiency higher than gasoline vehicles. • Range is comparable to that of gasoline vehicles depending on operating mode. • Maximum benefits achieved in stop and go and low speed city driving.
Propane	• Lower reactive hydrocarbon emissions compared to gasoline. • Lower particulate matter emissions copared to gasoline and diesel. • Lower air toxic emissions compared to gasoline. • Lower carbon monoxide emissions compared to gasoline. • Lower greenhouse gas emissions compared to gasoline	• 80% of range of gasoline vehicle; can add storage capacity to increase range. • No decline in performance compared to gasoline or diesel.

Source: http://www.on.ec.gc.ca/pollution/fpd/cpb/3016-e.html

Exhibit F

E85 Report

Ethanol Fleet Information

Start Date	End Date	Total Transactions	E-85 Transactions	Unleaded Transactions	Unleaded transaction @ G'Burg	E-85 Gallons	Unleaded Gallons	Unleaded Gallons @ Gburg	% E-85 used	% Unleaded Used	% Public Used
5/21/2002	7/11/2002	370	26	343	54	175.6	3654.6	596.8	5%	95%	
7/12/2002	7/31/2002	156	25	131	22	256.6	1493.3	260.1	15%	85%	
8/1/2002	8/31/2002	343	133	210	31	1530.5	2337.4	381.0	40%	60%	
9/1/2002	9/30/2002	421	182	239	36	1989.1	2615.2	443.6	43%	57%	
10/1/2002	10/31/2002	611	283	328	53	2495	3630.2	435.1	41%	59%	
11/1/2002	11/30/2002	362	124	238	37	1290.9	2710.9	417.7	32%	68%	
12/1/2002	12/31/2002	437	168	269	40	1795	3020.8	462.1	37%	63%	
1/1/2003	1/31/2003	433	151	282	50	1648.6	3062.7	627	35%	65%	
2/1/2003	2/28/2003	381	155	226	33	1871.8	2470.5	366.8	43%	57%	
3/1/2003	3/31/2003	438	185	253	33	2182.2	3007.6	401.5	42%	58%	
4/1/2003	4/30/2003	473	230	243	9	2540.2	2769.4	95.8	48%	52%	0.01%
TOTALS		4425	1662	2762	398	17775.5	30772.6	4487.5	35%	65%	0.01%

Retrofitting Emission Controls On Diesel-Powered Vehicles

March 2002

Manufacturers of Emission Controls Association
1660 L Street, NW * Suite 1100 * Washington, DC 20036
www.meca.org

Table of Contents

Figures

Executive Summary

Diesel engines are important power systems for onroad and offroad vehicles. These reliable, fuel-efficient, high torque engines power many of the world's heavy-duty trucks, buses, and nonroad vehicles. While diesel engines have many advantages, they have the disadvantage of emitting significant amounts of particulate matter (PM) and the oxides of nitrogen (NOx) into the atmosphere. Diesel engines also emit toxic air pollutants. Health experts have concluded that pollutants emitted by diesel engines adversely affect human health and contribute to acid rain, ground-level ozone and reduced visibility. Studies have shown that exposure to diesel exhaust causes lung damage and respiratory problems and there is increasing evidence that diesel emissions may cause cancer in humans.

Companies that manufacture emission controls have responded to the challenge of reducing the air pollution from diesel engines. Through their efforts, cost-effective retrofit technologies have been developed to reduce harmful emissions. In the mining, materials handling and trucking industries and in urban bus fleets, diesel retrofit technologies have demonstrated their ability to significantly reduce unwanted emissions at reasonable costs without jeopardizing vehicle performance.

The Manufacturers of Emission Controls Association (MECA) has received many inquiries regarding the installation of emission controls on diesel engines. Inquiries have included requests for technical information, information on past retrofit experiences, the types of retrofit control technologies available, the suitability of a given technology to a particular application and emission reductions that can be achieved. This document has been prepared to supplement information already made available by MECA on emission control technologies. Periodically, as new information becomes available, this document will be updated.

Available Control Technologies

Today, viable emission control technologies exist to reduce diesel exhaust emissions. The major retrofit technologies are listed below. Retrofit technologies to control PM, hydrocarbons (HC), carbon monoxide (CO) and toxics air pollutants include:

- Diesel oxidation catalysts
- Diesel particulate filters
- Enhanced combustion modifications
- Crankcase emission controls

Retrofit technologies to control NOx include:

- Exhaust gas recirculation (EGR)
- Selective catalytic reduction (SCR)
- Lean NOx catalysts
- Engine modifications plus PM controls

The retrofit of oxidation catalysts on diesel engines has been taking place for well over twenty years in the nonroad vehicle sector. Over 250,000 oxidation catalysts have been installed in underground mining and materials handling equipment. More recently, over 15,000 oxidation catalysts have been installed on urban bus engines as part of the U.S. Environmental Protection Agency's urban bus rebuild/retrofit program. Since 1995, over 40,000 systems have been installed on highway trucks, buses and other on road heavy-duty vehicles around the world. Oxidation catalysts installed on engines running 0.05 percent or less sulfur fuel have achieved particulate matter reductions of 20 to 50 percent, hydrocarbon reductions of 60 to 90 percent (including those HC species considered toxic), and significant reductions of carbon monoxide, smoke, and odor.

Over 1,000 buses have been retrofitted with oxidation catalysts in London, England and over 1,500 oxidation catalysts have been installed on trucks and buses in Sweden. In April 2001, the Hong Kong Department of Environmental Protection completed a pilot program involving the retrofit of 59 diesel vehicles with diesel oxidation catalysts. Based on this pilot program, Hong Kong plans retrofit about 40,000 trucks with diesel oxidation catalysts in the near future.

Development and commercialization of a number of second-generation diesel particulate filter systems have occurred. Second generation systems are capable of achieving 80 percent to greater than 90 percent PM reductions. Current filter designs are also capable of reducing toxic hydrocarbons by greater than 80%. In Europe, diesel vehicles retrofitted with filters are being offered commercially. Sweden's Environmental Zones Program has resulted in the commercial introduction of filters on buses and trucks. Over 2,500 vehicles have been equipped with passive filter systems in Sweden. Some of the filter-equipped buses in Sweden have operated in excess of 250,000 miles. Sweden's very low sulfur diesel fuel (<0.005% wt) allows this technology to perform as designed. Diesel particulate filters have also been installed on heavy-duty vehicles in the United States, Great Britain, Germany, Finland, Denmark, and France. Over 50,000 filter systems have been retrofitted on heavy-duty vehicles worldwide.

Recent work on off-road diesel vehicles in a Swiss tunneling project has shown that retrofitted diesel particulate filters not only substantially reduce PM mass emissions, but also significantly reduce the number of fine particles emitted. Health experts suspect that fine particles cause or contribute to respiratory disease because they travel to the deepest recesses of the lung when inhaled.

Recently, exhaust gas recirculation (EGR) and lean NOx catalysts have been retrofitted on heavy-duty diesel vehicles. EGR is capable of achieving about a 40 percent reduction in NOx emissions. Over 400 engines have been retrofitted with EGR systems in Europe and EGR retrofits are being introduced in the U.S. Lean NOx catalysts have demonstrated NOx reductions of about 10 to 20 percent in pilot programs in the U.S.

Selective catalytic reduction (SCR), using urea as a reducing agent, has also been installed on diesel-powered vehicles. SCR is capable of reducing NOx emissions from 75 to 90 percent while simultaneously reducing HC emissions up to 80 percent and PM emissions by 20 to 30 percent. Over 50 mobile SCR systems have been operational since 1995. Some vehicles have accumulated over 350,000 miles. SCR has been installed on heavy-duty trucks, marine vessels and locomotives. SCR is frequently applied to stationary diesel engines to achieve large NOx reductions in steady-state operations. Widespread use of SCR has not occurred on vehicles because of the challenges of applying this technology to engines that operate under widely varying load conditions. Demonstration projects intended to commercialize SCR systems for vehicles are underway at this time.

Emission control systems which combine catalysts, filters, and engine adjustments and components also are emerging and can be used for retrofit on diesel vehicles. One such technology has demonstrated over a 40 percent NOx reduction while maintaining very low particulate emissions. The system uses ceramic engine coatings combined with fuel injection timing retard and an oxidation catalyst and has been approved under the U.S. EPA's urban bus rebuild/retrofit program. Another example is a cerium-based fuel-borne catalyst filter system in combination with exhaust gas recirculation (EGR). A third system which provides substantial PM emission reductions and has been approved by the U.S. EPA under the Agency's urban rebuild/retrofit program employs a proprietary cam shaft in combination with an oxidation catalyst.

Diesel Retrofit Programs

Although technologies exist to reduce emissions from in-use diesel engines, care must be exercised to plan and implement a retrofit program to ensure that air quality benefits are realized. Successful implementation and operation of a diesel retrofit program depends on a number of elements. The program should define:

- which vehicles are suitable for retrofit;
- the appropriate emission control technology for each vehicle;
- the emission reductions that are desired or required;
- fuel quality needs (e.g. percent sulfur);
- operational and maintenance requirements; and
- training and education needs of vehicle operators and public.

Factors that influence vehicle selection include application, duty cycle, exhaust temperature and vehicle maintenance. Knowing this information will help in the selection of an appropriate technology for the vehicle. For optimum results, the engine of a vehicle should be rebuilt to manufacturer's specifications before a catalyst, filter system, or other emission control device is installed.

Conclusion

Although diesel emissions from mobile sources have raised health and welfare concerns, a number of effective control strategies exist or are being developed that can greatly reduce the emissions from diesel-powered vehicles. Retrofit technologies including diesel oxidation catalysts, diesel particulate filters, EGR, lean NOx catalysts, selective catalytic reduction, and engine component and management devices have been successfully demonstrated on both onroad and nonroad vehicles. These technologies can greatly reduce particulate matter and other harmful pollutants from diesel exhaust.

1.0 Introduction

Diesel engines provide important fuel economy and durability advantages for large heavy-duty trucks, buses, and nonroad equipment. They are often the power plant of choice for heavy-duty applications. While they have many advantages, they also have the disadvantage of emitting significant amounts of particulate matter (PM) and the oxides of nitrogen (NOx) and lesser amounts of hydrocarbon (HC), carbon monoxide (CO) and toxic air pollutants.

Particles emitted from diesel engines are small – in most cases less than 2.5 microns in diameter. The particles are complex consisting of an uncombusted carbon core, adsorbed hydrocarbons from engine oil and diesel fuel, adsorbed sulfates, water, and inorganic materials such as those produced by engine wear. Because of their extremely small size and composition, the particles emitted by diesel engines have raised many health concerns. Health experts have expressed concern that diesel PM may contribute to or aggravate chronic lung diseases such as asthma, bronchitis, and emphysema.

There is growing evidence that exposure to diesel PM may increase the risk of cancer in humans. A comprehensive assessment of available health information, carried out by the International Agency For Research on Cancer (IARC) in June 1988 concluded that diesel particulate is probably carcinogenic to humans. The term "carcinogen" is used by the IARC to denote an agent that is capable of increasing the incidence of malignant tumors. In August 1998, California's Air Resources Board identified PM emissions from diesel-fueled engines as a toxic air contaminant. Recent health studies in Europe suggest that the carbon core of diesel particulate emissions poses a serious health concern. In 2000, the U.S. EPA declared diesel PM to be a "likely human carcinogen."

The NOx emissions from diesel engines also pose a number of health concerns. Once in the atmosphere, the oxides of nitrogen react with volatile organic compounds (VOCs) in the presence of sunlight to form ozone. Ozone is reactive and corrosive gas that contributes to many respiratory problems. Ozone is particularly harmful to children and the elderly. The American Lung Association (ALA) reported 10,000 to 15,000 hospital admissions and 30,000 to 50,000 emergency room visits in the 1993 and 1994 high ozone season in 13 American cities because of elevated ozone levels. NOx emissions themselves can damage respiratory systems and lower resistance to respiratory infection. As with ozone, children and the elderly are particularly susceptible to NOx emissions.

In addition to the undesirable health affects associated with diesel exhaust, diesel emissions also adversely impact the environment. Diesel particulate emissions soil buildings and impair visibility. Diesel NOx emissions contribute to the problems of acid rain and ground-level ozone. From a quality of life perspective, there is increasing interest in reducing the smoke and odors associated from diesel engines.

Despite health and environmental concerns, the diesel engine remains a popular means of powering trucks, buses and other heavy equipment. Most buses and heavy-duty trucks are powered by diesel engines for good reasons. Diesel engines are reliable, fuel efficient, easy to repair and inexpensive to operate. One of the most impressive attributes of the diesel engine is its durability. In heavy-duty trucks, some engines have achieved operating lives of 1,000,000 miles; some engines power city buses for up to 15-20 years.

A number of countries worldwide have established emission limits for new diesel engines. However, some diesel engines have very long operating lives, older uncontrolled diesel vehicles will continue to make up a significant portion of the heavy-duty vehicle fleet in these countries for years to come. Given the health and environmental concerns associated with diesel engines, there in increasing interest to retrofit older, “dirtier” diesel engines while newer, “cleaner” diesel engines enter the marketplace.

2.0 Available Retrofit Controls

Several types of emission control systems can be installed on a diesel vehicle.

Diesel oxidation catalysts (DOCs) installed on a vehicle's exhaust system can reduce the soluble organic fraction of the particulate matter in the exhaust by as much as 90 percent and total PM by as much as 25 to over 50 percent depending on the composition of the PM being emitted. Diesel oxidation catalysts can reduce smoke emissions from older vehicles by over 50 percent and virtually eliminate the obnoxious odors associated with diesel exhaust. Oxidation catalysts can reduce more than 90 percent of the carbon monoxide and hydrocarbon emissions and more than 70 percent toxic hydrocarbon emissions in diesel exhaust.

Diesel particulate filters (DPFs) have also been retrofitted to existing vehicles. Diesel particulate filters can achieve up to, and in some cases greater than, a 90 percent reduction in particulate matter. Filters are extremely effective in controlling the carbon fraction of the particulate, the portion of the particulate that some health experts believe may be the PM component of greatest concern. Particulate filters can be designed to control up to 90 percent or more of the toxic hydrocarbons emitted by a diesel engine. Catalytic exhaust control and particulate filter technologies have been shown to decrease the levels of polyaromatic hydrocarbons, nitro-polyaromatic hydrocarbons, and the mutagenic activity of diesel PM.

More recently, *exhaust gas recirculation (EGR)* and *lean NOx catalysts* have been retrofitted on heavy-duty diesel vehicles. EGR is capable of achieving a 40 percent reduction in NOx emissions or more. Lean NOx catalysts have demonstrated NOx reductions of 10 to 20 percent.

Selective catalytic reduction (SCR) using urea as a reducing agent has been shown to be effective in reducing NOx emissions by up to 90 percent while simultaneously reducing HC emissions by 50 to 90 percent and PM emissions by 30 to 50 percent.

Crankcase emission control technology can be retrofitted on turbocharged diesel engines to eliminate crankcase emissions.

In some cases, oxidation catalyst and filter technologies can be combined with engine management techniques, e.g., injection timing retard and exhaust gas recirculation (EGR) or with ceramic engine coatings or other technologies, to provide significant control of both particulate and NOx.

2.1 Diesel Oxidation Catalysts

The diesel oxidation catalyst (DOC) has become a leading retrofit control strategy in both the onroad and nonroad sectors throughout the world, reducing not only PM emissions but also CO and HC emissions. Using oxidation catalysts on diesel-powered vehicles is not a new concept. Oxidation catalysts have been installed on over 250,000 off-road vehicles around the world for over 30 years. Over 1.5 million oxidation catalysts have been installed on new heavy-duty highway trucks since 1994 in the U.S. These systems have operated trouble free for hundreds of thousands of miles. Recently, nearly 20,000 oxidation catalysts were installed on urban buses and highway trucks in Europe and the U.S. Oxidation catalysts can be used not only with conventional diesel fuel, but have also been shown effective with biodiesel and emulsified diesel fuels, ethanol/diesel blends and other alternative diesel fuels.

2.1.1 Operating Characteristics and Control Capabilities

In most applications, a diesel oxidation catalyst consists of a stainless steel canister that contains a honeycomb structure called a substrate or catalyst support. There are no moving parts, just large amounts of interior surface area. The interior surfaces are coated with catalytic metals such as platinum or palladium. It is called an oxidation catalyst because the device converts exhaust gas pollutants into harmless gases by means of chemical oxidation. In the case of diesel exhaust, the catalyst oxidizes carbon monoxide (CO), gaseous hydrocarbons (HCs) and the liquid hydrocarbons adsorbed on carbon particles. In the field of mobile source emission control, liquid hydrocarbons adsorbed on the carbon particles in engine exhaust are referred to as the soluble organic fraction (SOF) – the soluble part of the particulate matter in the exhaust. Diesel oxidation catalysts are efficient at converting the soluble organic fraction of diesel particulate matter into carbon dioxide and water. A conceptual diagram of a diesel oxidation catalyst is shown in Figure 1.

Diesel Oxidation Catalyst

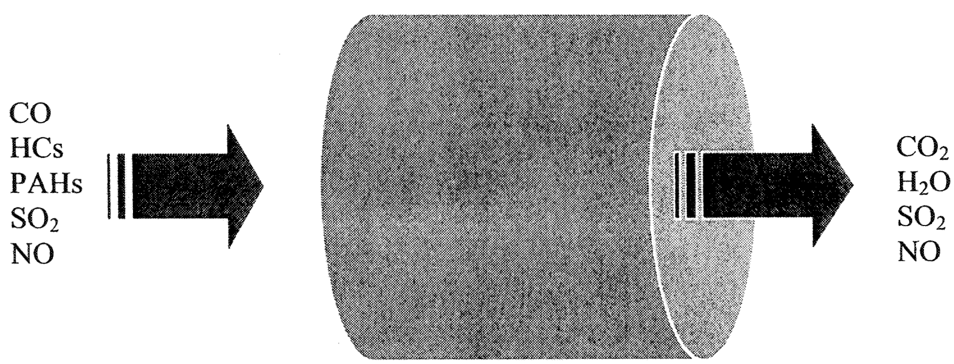


Figure 1

The level of total particulate reduction is influenced in part by the percentage of SOF in the particulate. For example, a Society of Automotive Engineers (SAE) Technical Paper (SAE No. 900600) reported that oxidation catalysts could reduce the SOF of the particulate by 90 percent under certain operating conditions, and could reduce total particulate emissions by 40 to 50 percent. Destruction of the SOF is important since this portion of the particulate emissions contains numerous chemical pollutants that are of particular concern to health experts.

Oxidation catalysts have proven effective at reducing particulate and smoke emissions on older vehicles. Under the U.S. EPA's urban bus rebuild/retrofit program, five manufacturers have certified diesel oxidation catalysts as providing at least a 25 percent reduction in PM emissions for in-use urban buses. Certification data also indicates that oxidation catalysts achieve substantial reductions in CO and HC emissions.

Combining an oxidation catalyst with engine management techniques can be used to reduce NOx emissions from diesel engines. This is achieved by adjusting the engine for low NOx emissions which is typically accompanied by increased CO, HC and particulate emissions. An oxidation catalyst can be added to the exhaust system to offset these increases, lowering emissions of all pollutants. Often, the increases in CO, HC, and particulate can be reduced to levels lower than otherwise could be achieved. A system approved under EPA's urban bus rebuild/retrofit program uses an oxidation catalyst combined with proprietary ceramic engine coatings and injection timing retard to achieve a greater than 40 percent NOx reduction while maintaining low particulate emissions. This same system has also been approved as reducing PM emissions to below 0.1 g/bhp-hr. A system employing catalysts and a proprietary camshaft has also been approved providing PM emissions below 0.1 g/bhp-hr. A third system using an electronic supercharger and an oxidation catalyst has been approved providing PM emissions of less than 0.1 g/bhp-hr.

2.1.2. Impact of Sulfur in Diesel Fuel on Catalyst Technologies

The sulfur content of diesel fuel is critical to applying catalyst technology. Catalysts used to oxidize the SOF of the particulate can also oxidize sulfur dioxide to form sulfates, which is counted as part of the particulate. This reaction is not only dependent on the level of sulfur in the fuel, but also the temperature of the exhaust gases. Catalyst formulations have been developed which selectively oxidize the SOF while minimizing oxidation of the sulfur dioxide. However, the lower the sulfur content in the fuel, the greater the opportunity to maximize the effectiveness of oxidation catalyst technology for both better total control of PM and greater control of toxic HCs. Lower sulfur fuel (0.05% wt.), which was introduced in 1993 throughout the U.S., has facilitated the application of catalyst technology to diesel-powered vehicles. Furthermore, the very low fuel sulfur content (<0.003% wt.) available in several European countries and more recently in the U.S. has further enhanced catalyst performance.

Catalysts have been installed on vehicles that run on fuel that contains more than 0.05% wt. sulfur. Performance of an oxidation catalyst on fuel with higher sulfur content will vary with catalyst formulation, engine type, and duty cycle. In all cases, however, catalyst performance is adversely affected by the presence of sulfur in the fuel.

2.1.3 Operating Experience

Oxidation catalysts can play a significant role in removing particulate and smoke from existing diesel engines and, as noted above, can be used in combination with engine management techniques to control NOx emissions. Retrofitting oxidation catalysts on existing diesel engines is relatively straightforward. For example, in many applications the oxidation catalyst can be retrofitted as a muffler replacement. Indeed, many of the catalysts used on nonroad vehicles are retrofits. Recently, nearly 20,000 oxidation catalysts were installed on urban buses and trucks in Europe and the U.S. The earliest installations have accumulated well over 150,000 km and have proven to be virtually maintenance free.

Oxidation catalysts have also been retrofitted in other areas of the world. In Mexico, over 8,000 heavy-duty vehicles have been retrofitted with oxidation catalysts. Hong Kong recently embarked on a large retrofit program that involves 2,000 urban buses and more than 40,000 medium-duty diesel vehicles. The number of retrofits worldwide is large and growing.

On the nonroad side, oxidation catalysts have been retrofitted to diesel vehicles for over 30 years with over 250,000 installations having been completed to date. A significant percentage of these units have been equipped to mining and materials handling vehicles, but construction equipment and other types of nonroad equipment have been retrofitted as well. PM emissions as well as CO and HC emission reductions are targeted in these industries for occupational health concerns. Typically, these systems operate trouble free for several thousand operating hours and are normally replaced only when an engine undergoes a rebuild.

2.1.4 Costs

Diesel oxidation catalysts are estimated to cost from $425 to $1,750 per catalyst depending on engine size, sales volume and whether the installation is muffler replacement or an in-line installation. Many systems are designed to replace the original muffler on the vehicle and, as such, not only provide emission control but also provide the appropriate level of noise attenuation. In most cases, oxidation catalysts are easy to install. Installations typically take less than 2 hours.

For the systems which use additional technologies to reach the very low 0.1 g/bhp-hr PM emission level which have been certified or for certification under the U.S. EPA's urban bus rebuild/retrofit program, additional costs will be incurred for the purchase and application of ceramic engine coatings, turbochargers, and/or modified cam shafts. Using catalyst technology in combination with modified engine calibrations (e.g., injection timing retard) to reduce NOx emissions will not necessarily add to the cost of the system, but may require additional labor during installation and calibration.

Nonroad diesel equipment is characterized by widely varying horsepower (hp) ratings. Retrofit control technologies have been installed on vehicles with horsepower ratings under 50 hp to vehicles powered by engines in excess of 2,000 hp. Both muffler replacement catalyst and in-line units have been installed. Many oxidation catalysts are designed to simply replace the original equipment manufacturer's muffler.

2.2 Diesel Particulate Filters

2.2.1 Operating Characteristics and Performance

As the name implies, diesel particulate filters remove particulate matter in diesel exhaust by filtering exhaust from the engine. They can be installed on vehicles or stationary diesel engines. Since a filter can fill up over time, engineers that design filter systems must provide a means of burning off or removing accumulated particulate matter. A convenient means of disposing of accumulated particulate matter is to burn or oxidize it on the filter when exhaust temperatures are adequate. By burning off trapped material, the filter is cleaned or "regenerated." Filters that regenerate in this fashion cannot be used in all situations.

In some nonroad applications, disposable filter systems have been used. A disposable filter is sized to collect particulate for a working shift or some other predetermined period of time. After a prescribe amount of time or when backpressure limits are approached, the filter is removed and cleaned or discarded. To ensure proper operation, filter systems are designed for the particular vehicle and vehicle application.

Filter Material A number of filter materials have been used in diesel particulate filters including: ceramic and silicon carbide materials, fiber wound cartridges, knitted silica fiber coils, ceramic foam, wire mesh, sintered metal substrates, and temperature resistant paper in the case of disposable filters. Collection efficiencies of these filters range from 50 to over 90 percent. Filter materials capture particulate matter by interception, impaction and diffusion. Filter efficiency has rarely been a problem with the filter materials listed above, but work has continued to: 1) optimize filter efficiency and minimize back pressure, 2) improve the radial flow of oxidation in the filter during regeneration, and 3) improve the mechanical strength of filter designs. Figure 2 provides a diagram of a typical filter system.

Diesel Particulate Filter

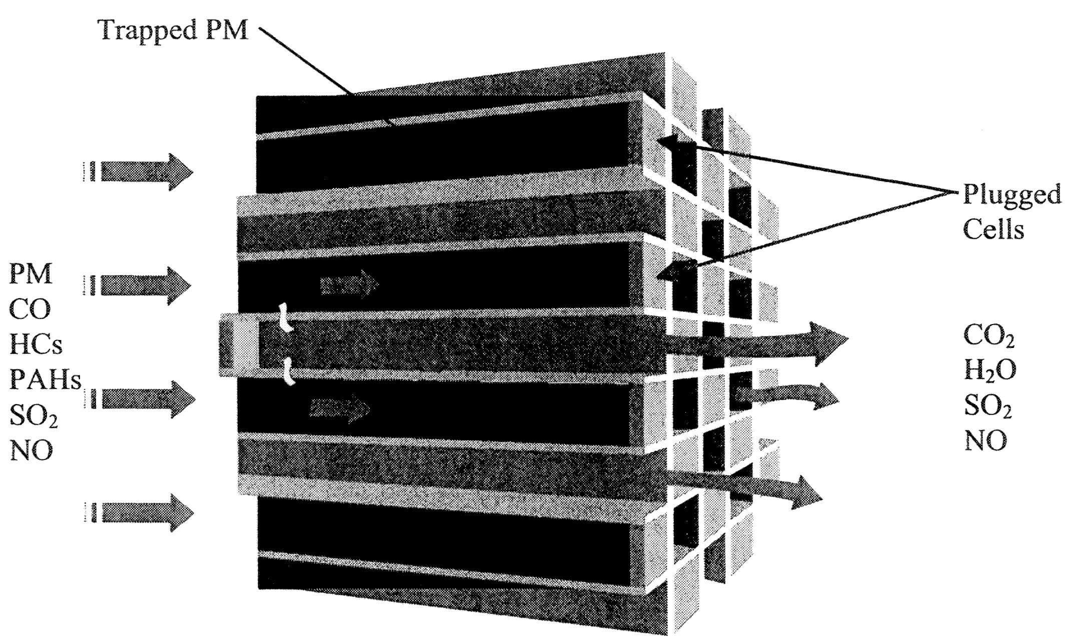


Figure 2

In the figure, particulate-laden exhaust enters the filter from the left. Because the cells of the filter are capped at the downstream end, exhaust cannot exit the cell directly. Instead, exhaust gas passes through the porous walls of the filter cells. In the process, particulate matter is deposited on the upstream side of the cell wall. Cleaned exhaust gas exits the filter to the right.

Regeneration Many techniques can be used to regenerate a diesel particulate filter. Some of these techniques are used together in the same filter system to achieve efficient regeneration. Both on- and off-board regeneration systems exist. The major regeneration techniques are listed below.

- Catalyst-based regeneration using a catalyst applied to the surfaces of the filter. A base or precious metal coating applied to the surface of the filter reduces the ignition temperature necessary to oxidize accumulated particulate matter.

- Catalyst-based regeneration using an upstream oxidation catalyst. In this technique, an oxidation catalyst is placed upstream of the filter to facilitate oxidation of nitric oxide (NO) to nitrogen dioxide (NO_2). The nitrogen dioxide adsorbs on the collected particulate substantially reducing the temperature required to regenerate the filter;

- Fuel-borne catalysts. Fuel-borne catalysts reduce the temperature required for ignition of trapped particulate matter.

- Air-intake throttling. Throttling the air intake to one or more of the engine cylinders can increase the exhaust temperature and facilitate filter regeneration.

- Post top-dead-center (TDC) fuel injection. Injecting small amounts of fuel in the cylinders of a diesel engine after pistons have reached TDC introduces a small amount of unburned fuel in the engine's exhaust gases. This unburned fuel can then be oxidized in the particulate filter to combust accumulated particulate matter.

- On-board fuel burners or electrical heaters. Fuel burners or electrical heaters upstream of the filter can provide sufficient exhaust temperatures to ignite accumulated and regenerate the filter.

- Off-board electrical heaters. Off-board regeneration stations combust trapped particulate matter by blowing hot air through the filter system.

The experience with catalyzed filters indicates that there is a virtually complete reduction in odor and in the soluble organic fraction of the particulate, but some catalysts may increase sulfate emissions. Companies utilizing these catalysts to provide regeneration for their filters have modified catalyst formulations to reduce sulfates emissions to acceptable levels. Low sulfur fuel (0.0015% wt) is becoming available in the U.S. and has greatly facilitated these efforts.

In some situations, installation of a filter system on a vehicle may cause a very slight fuel economy penalty. This fuel penalty is due to the backpressure of the filter system. As noted above, some filter regeneration methods involve the use of fuel burners and to the extent those methods are used, there will be an additional fuel economy penalty. Many filter systems, however, have been optimized to minimize, or nearly eliminate, any noticeable fuel economy penalty. For example, in a demonstration program in Athens, Greece, no noticeable fuel penalty was recorded when the filter was regenerated with a cerium fuel-borne catalyst (SAE 920363). More recently, experience in the New York City Transit program and in the San Diego school bus program has shown that fuel penalties for filters are zero or less than one percent.

Filter systems do not appear to cause any additional engine wear or affect vehicle maintenance. Concerning maintenance of the filter system itself, manufacturers are designing systems to minimize maintenance requirements during the useful life of the vehicle. In some cases, accumulated lubricating oil ash may have to be periodically removed, however. Manufacturers provide the end-user with appropriate removal procedures.

Filter systems have been designed so that vehicle drivability is not affected, or at least effects can be minimized, most notably by limiting exhaust backpressure. Diesel particulate filter systems, which replace mufflers in retrofit applications, have achieved sound attenuation equal to a standard muffler.

2.2.2 The Impact of Sulfur in Diesel Fuel on Diesel Particulate Filters

Sulfur in diesel fuel significantly affects the reliability, durability, and emissions performance of catalyst-based diesel particulate filters. Sulfur affects filter performance by inhibiting the performance of catalytic materials upstream of or on the filter. Sulfur also competes with chemical reactions intended to reduce pollutant emissions and creates particulate matter through catalytic sulfate formation. Catalyst-based diesel particulate filter technology works best when fuel sulfur levels are less than 0.0015% wt. In general, the less sulfur in the fuel, the better the technology performs.

Particulate filter technology can be successfully used in applications where the fuel sulfur level is greater than 0.0015 wt., but only after a careful assessment has been made of the fuel sulfur level, the engine, the type of filter system, the operating conditions and the emission reductions desired.

2.2.3 Operating Experience

Limited diesel particulate filter retrofit demonstration programs began in the 1980s and continued in the early 1990s. The number of vehicles retrofitted, the number of programs and the interest in new programs has grown significantly over the past few years. Today, second-generation filter systems can reduce PM emissions 80 to greater than 90 percent. In Europe, vehicles equipped with diesel particulate filters are being offered commercially. Peugeot is selling new light-duty vehicles equipped with filter systems. Over 80,000 filter-equipped cars have been sold and no performance or maintenance issues have been reported. Other European automobile manufacturers have announced plans to install filter systems. Sweden's Environmental Zones program resulted in the commercial introduction of diesel particulate filters on urban buses. More than 2,500 buses have been equipped with passive filter systems in Sweden. Some of these buses have accumulated more than 250,000 miles of service.

Diesel particulate filters have been installed on nonroad equipment since 1986. Over 20,000 active and passive systems have been installed as either original equipment or as a retrofit worldwide. Some nonroad filter systems have been operated for over 15,000 hours or over 5 years and are still in use. Examples of nonroad equipment equipped with filters include: mining equipment, material-handling equipment such as forklift trucks, street sweepers and utility vehicles. Germany, Austria and Switzerland have established mandatory filter requirements for underground mining equipment.

Diesel particulate filters can be combined with exhaust gas recirculation (EGR) or selective catalytic reduction (SCR) to achieve significant NOx and PM reductions. Engines with EGR and a filter system can achieve NOx reductions of over 40 percent and PM reductions of greater than 90 percent. Engines equipped with SCR and a filter can achieve NOx reductions of 75 to 90 percent and PM reductions greater than 90 percent. Combined NOx and PM reductions can also be achieved by recalibrating the engine to minimize NOx while using a filter to capture increased PM emissions. A lean NOx catalyst added to an exhaust system using a particulate filter can reduce NOx emissions from 10 to 20 percent.

2.2.4 Costs

Filters are currently being sold for about $7,500 each. Prices vary depending on the size of the engine being retrofit, the sales volume (the number of vehicles being retrofit), the amount of particulate matter emitted by the engine, the emission target that must be achieved the regeneration method and other factors. Filters that are sold as muffler replacements generally cost more that in-line filters.

2.3 Exhaust Gas Recirculation (EGR)

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

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

2.3.1 Operating Characteristics and Control Capabilities

EGR systems are capable of achieving NOx reductions of more than 40 percent.

2.3.2 Operating Experience

Over 400 EGR systems have been installed on bus engines in Europe. EGR retrofit systems are now being installed in the U.S on solid waste collection vehicles, buses and some city-owned vehicles. Technology demonstration programs have been conducted in Houston, TX and Los Angeles, CA. Additional demonstration programs are being planned in the San Francisco Bay area; Sacramento, CA; Los Angeles, CA; and Washington DC.

2.3.3 Costs

The cost of retrofitting EGR on a typical bus or truck engine is about $13-15,000.

2.4 Selective Catalytic Reduction (SCR)

SCR has been used to control NOx emissions from stationary sources for over 15 years. More recently, it has been applied to select mobile sources including trucks, marine vessels, and locomotives. Applying SCR to diesel-powered vehicles provides simultaneous reductions of NOx, PM, and HC emissions.

2.4.1 Operating Characteristics and Control Capabilities

An SCR system uses a metallic wash-coated or homogeneous extruded catalyst and a chemical reagent to convert nitrogen oxides to molecular nitrogen and oxygen in the exhaust stream. In mobile source applications, an aqueous urea solution is usually the preferred reductant. The reductant is added at a rate calculated by an algorithm that estimates the amount of NOx present in the exhaust stream. The algorithm relates NOx emissions to engine parameters such as engine revolutions per minute (rpm), exhaust temperature, backpressure and load. As exhaust and reductant pass over the SCR catalyst, chemical reactions occur that reduce NOx emissions. Open loop SCR systems can reduce NOx emissions of 75 to 90 percent. Closed loop systems on stationary engines can achieve NOx reductions of greater than 95 percent. SCR systems reduce HC emissions up to 80 percent and PM emissions 20 to 30 percent. They also reduce the characteristic odor produced by a diesel engine and diesel smoke. Like all catalyst-based emission control technologies, SCR performance is enhanced by the use of low sulfur fuel. Low sulfur fuel is not a requirement, however. Application of SCR to vehicles and equipment with transient operating conditions offers special challenges and it may not be appropriate for all vehicle applications. Care must be taken to design a SCR system for the specific vehicle or equipment application involved.

2.4.2 Operating Experience

SCR is currently being used on both onroad and nonroad vehicles. Applications include trucks, marine vessels and locomotives. Over 50 mobile systems have been installed and operational since 1995. Some vehicles have been operated for over 350,000 miles.

SCR systems have also been installed on marine vessels and locomotives. Over 20 marine vessels have been equipped with SCR. The marine engines range from approximately 1250 hp to almost 10,000 hp and the installations have been in operation since the early to mid-1990s. Recently, the Swedish company SCA Graphic Paper announced it will equip its fleet of vessels with SCR technology to reduce NOx emissions by 90 percent.

2.4.3 Costs

SCR costs vary depending on the size of the diesel engine that is being retrofitted. The cost of SCR systems for buses, trucks and other mobile sources is difficult to estimate because this is a new application for this emission control technology. At this time, however, costs are expected to range from $10,000 to $50,000 per vehicle depending on the number of vehicles to be retrofitted and other factors such as engine size, etc. It is expected that costs will decrease as new NOx sensors are developed and sales increase.

2.5 Lean NOx Catalysts

Controlling NOx emissions from a diesel engine is inherently difficult because diesel engines are designed to run lean. In the oxygen-rich environment of diesel exhaust, it is difficult to chemically reduce NOx to molecular nitrogen. The conversion of NOx to molecular nitrogen in the exhaust stream requires a reductant (HC, CO or H_2) and under typical engine operating conditions, sufficient quantities of reductant are not present to facilitate the conversion of NOx to nitrogen.

Some lean NOx catalyst systems inject a small amount of diesel fuel or other reductant into the exhaust. The fuel or other hydrocarbon reductant serves as a reducing agent for the catalytic conversion of NOx to N_2. Other systems operate passively at reduced NOx conversion rates. The catalyst substrate is a porous material often made of zeolite. The substrate provides microscopic sites that are fuel/hydrocarbon rich where reduction reactions can take place. Without the added fuel and catalyst, reduction reactions that convert NOx to N_2 would not take place because of excess oxygen present in the exhaust. A hydrocarbon/NOx ratio of up to 6/1 is needed to achieve good NOx reductions. Since the fuel used to reduce NOx does not produce mechanical energy, lean NOx catalysts typically operate with a fuel penalty of about 3 percent. Currently, peak NOx conversion efficiencies typically are around 10 to 20 percent. Only a limited number of vehicles have been equipped with lean NOx catalyst systems in the U.S.

Two types of lean NOx catalyst systems have emerged: a low temperature catalyst based on platinum and a high temperature catalyst utilizing base metals, usually copper. Each catalyst is capable of controlling NOx over a narrow temperature range. Combining high and low temperature lean NOx catalyst systems broadens the temperature range over which they convert NOx making them more suitable for practical applications.

A low NOx control version of this technology has been incorporated into the exhaust systems of European passenger cars equipped with diesel oxidation catalysts. These systems have achieved NOx reductions of about 15 percent. A higher efficiency version of this technology capable of 50 to 70 percent NOx reductions is under development. Advances have been made in improving the durability, control efficiency and operating windows of this technology. Lean NOx catalysts are sensitive to sulfur and require low sulfur diesel fuel.

2.6 Crankcase Emission Control

Today, in most turbocharged aftercooled diesel engines, the crankcase breather is vented to the atmosphere often using a downward directed draft tube. While a rudimentary filter is often installed on the crankcase breather, substantial amount of particulate matter is released to the atmosphere. Emissions through the breather may exceed 0.7 g/bhp-hr during idle conditions on recent model year engines.

One solution to this emissions problem is the use of a multi-stage filter designed to collect, coalesce, and return the emitted lube oil to the engine's sump. Filtered gases are returned to the intake system, balancing the differential pressures involved. Typical systems consist of a filter housing, a pressure regulator, a pressure relief valve and an oil check valve. These systems greatly reduce crankcase emissions.

3.0 Operating a Diesel Emission Retrofit Control Program

The successful operation of a diesel emission retrofit control program depends on a number of elements. The program should define:

- which vehicles are suitable for retrofit;
- the appropriate emission control technology for each vehicle;
- the emission reductions that are desired or required;
- fuel quality needs (e.g. percent sulfur);
- operational and maintenance requirements; and
- training and education needs of vehicle operators and public.

Two highly successful retrofit programs are currently operating in the world: the U.S. EPA's Urban Bus Retrofit/Rebuild Program and Sweden's Environmental Zones Program.

The U.S. program affects all major urban areas in the United States and requires that, at the time of engine rebuild, certified retrofit emission control technology or certified engine rebuild kits that provide a 25% reduction in PM emissions be installed on the urban bus, provided a cost cap is met. If a technology has been certified to meet a 0.1 g/bhp-hr PM emission limit for an engine, then the transit authority must install this retrofit technology at the time of rebuild, again, provided that a cost cap is met. The transit operators also have the ability to use a fleet average emission limit where a combination of using certified retrofit technologies and certified engine rebuild kits, repowering with new cleaner engines, or retiring old buses can be used.

The Swedish program affects the three largest cities in that country -- Stockholm, Goteborg, and Malmo. Beginning in July 1996, in order for a heavy-duty diesel vehicle to be operated in the downtown areas it was required to meet EURO 2 emissions standards. However, older vehicles were exempted from the restriction if they were equipped with an approved retrofit emissions control device. Both oxidation catalysts and diesel particular filters have been retrofitted under this program.

The Air Resources Board (ARB) identified diesel PM as a toxic air contaminant in August 1998. This action led to development of a plan to reduce the risk from diesel PM emissions, which was approved by the ARB in September 2000. Identified in the Plan, called the "Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles," are measures to dramatically reduce emission levels of diesel PM. The measures fall into three broad categories: 1) more stringent engine exhaust emission standards for new on- and off-road vehicles and equipment, continuing the trend towards near-zero PM emissions begun in the late 1980s; 2) retrofitting existing on- and off-road engines with devices that will reduce diesel PM by 85 percent or more; and 3) improving and implementing programs that will maintain mandated exhaust emission levels throughout the life of the vehicle or equipment.

The Plan emphasizes retrofit and in-use controls for existing diesel engines because these engines typically have useful lifetimes in excess of 400,000 miles. An engine is rebuilt, rather than replaced, when it reaches the end of its useful lifetime. Current regulations, except those applying to urban transit buses, allow the engine to be rebuilt to meet the standards in effect at the time of manufacture. To address this problem, the report recommends a large-scale program to retrofit diesel particulate filters, and other feasible technologies, on existing diesel engines.

In February 2000, ARB took an important first step in curbing diesel emissions in California by adopting a public transit bus fleet regulation. The rule requires significant NOx and PM reductions. PM reductions are achieved by the purchase of new, low-emitting buses; the repowering older, high-emitting buses and the installation of PM emission controls. In addition, for fiscal year 2000/2001, the Governor budgeted $50 million for a program aimed at replacing old school buses (3.75 million) and retrofitting existing buses with diesel particulate filters (12.5 million). ARB plans to implement similar emission control programs for Solid Waste Collection Vehicles, Fuel Tankers and other vehicle fleets. The Solid Waste Collection Vehicle rule is scheduled to be adopted in June 2002.

For the past several years, ARB has had an interim "Retrofit Verification Procedure" in place to verify the performance of diesel retrofit technologies used in California. The procedures specify the testing and other requirements a manufacturer must meet to have a retrofit device verified in California. The procedures allow companies to verify technologies that achieve different PM reduction levels. Level 1 technologies must reduce PM emissions from 25 to less than 50 percent, Level 2 technologies 50 to less than 85 percent, and Level 3 technologies 85 percent and above. NOx control technologies must achieve a reduction of at least 15 percent. ARB plans to finalize these verification procedures in May 2002. ARB's Diesel Mobile Programs web site is located at: http://arbis.arb.ca.gov/diesel/mobile.htm.

The U.S. EPA recently announced the creation of a Voluntary Diesel Retrofit Program for heavy-duty vehicles not covered by the federal Urban Bus Retrofit Program. Trucks, buses, and off-road equipment are covered by the program. Under the program, if a state uses a retrofit technology approved under the program, they are eligible to receive state implementation plan (SIP) emission reduction credits. EPA received 70,000 retrofit commitments in 2001. EPA set a goal of receiving 130,000 retrofit commitments in 2002. The EPA program sets up a protocol for calculating credits, the structure of a third-party verification system for approving retrofit technologies, and an-use testing requirements to ensure that the emission reduction credits claimed are achieved in the field. Information regarding EPA's Voluntary Diesel Retrofit Program can be found at: http://www.epa.gov/otaq/retrofit/.

3.1 Vehicle Selection

Although in theory retrofit control technologies can be applied to any vehicle, it may be easier to administer and control a program by targeting vehicle fleets. Some examples of captured fleets include urban bus fleets, school buses, privately-owned delivery fleets, publicly- and privately-owned construction equipment, publicly-owned diesel-powered vehicles, and construction equipment at a given construction site. The advantage of targeting these vehicles is that they are often centrally fueled and are typically maintained in a more controlled fashion. Also, training of operators and maintenance personnel is more easily achieved.

3.2 Retrofit Control Technology Options

A variety of retrofit control technologies are available for use in a retrofit control program as discussed in Section 2.0. The technologies to be used should be selected based on desired reductions in diesel emissions, cost, and applicability.

As outlined in the following sections, different technologies afford varying degrees of emissions reductions. Some technologies target PM emissions alone, while others target not only PM emissions but emissions of CO and HC as well. Other technologies or technologies in combination with engine management strategies can provide reductions in NOx emissions as well.

Different technologies can also result in different levels of control. Some technologies can offer very high reductions in some applications whereas more modest reductions may be offered by other technologies with broader application.

Costs of the different technologies should also be considered.

The applicability of the different retrofit control technologies should also be considered. Some technologies can be universally applied, such as oxidation catalysts, while others may be application specific, such as a diesel particulate filter system that may require a certain exhaust gas temperature to regenerate. In the instances where the technology is application specific, it should be insured that the application is suitable.

It is also important to insure that the emissions reductions expected are in fact achieved in use. A retrofit technology provider to a retrofit program should provide data to substantiate the claimed reductions. This data should have been generated from a recognized test facility over a recognized test cycle, e.g., U.S., European certification cycles, or other local test requirements. The ability of the technology to provide emissions reductions over time should also be demonstrated. One possibility would be to accept the certifications of technologies already certified under EPA's urban bus program, California or EPA's verification procedures, or Sweden's Clean Cities Program. In the case where the technology has not been certified under one of these programs, the same type of data should be required.

3.3 Education and Training

Key elements of a diesel emissions retrofit control program are education and training. Both public and operator education on the benefits of, and needs for, a retrofit control program enhances the success and acceptance of the program.

Both vehicle operators and maintenance personnel should be trained on how a particular retrofit device operates and any special maintenance that may be required. For example, special lubricating oil requirements should be defined if necessary.

3.4 Incentives and Regulations

Incentives can also be used to encourage the use of diesel retrofit control technologies. Incentives can include:

- a reduction in vehicle registration fees, taxes, or user fees;
- retrofit in lieu of paying smoke inspection violation fines;
- an exemption from roadside smoke inspections;
- an exemption from use restrictions;
- clean diesel awards/publicity for fleet operators who use retrofit control technologies; and
- partial funding by government agencies.

Retrofit advocates have suggested that retrofitted vehicles be required for any publicly funded construction project in an urban area.

Retrofit technologies offer a viable means of reducing emissions from trucks, buses, construction equipment and other heavy-duty vehicles that are currently in use. There are enormous health and environmental benefits that can be achieved by implementing diesel retrofit programs. Under current EPA policy, States can take credit for the emission reductions achieved in retrofit programs in their State Implementation Plan (SIP), plans that describes a state's strategy for achieving and maintaining National Ambient Air Quality Standards. EPA policy allows 3 percent of the total emission reductions needed to meet air quality standards to be from voluntary mobile source emission reduction programs. EPA is encouraging States, local agencies, industries, and environmental organizations to promote EPA's Voluntary Diesel Retrofit Program and to incorporate this program into their SIP.

4.0 Technical Issues to be Considered When Retrofitting Emission Controls

When retrofitting emission control technologies to existing vehicles, several factors should be considered. These factors include:

- fuel quality,
- the vehicle and engine application, and
- vehicle maintenance.

These factors will influence the selection of an appropriate emission control technology. The emission reduction target, the emission reduction desired for a specific pollutant, may also play an important role in technology selection. For optimum results, the existing engine should be rebuilt to manufacturer's specifications before the emission control system is installed.

4.1 Fuel Quality

Care must be taken to properly match the retrofit control technology to the quality of the fuel that is available. For catalyst systems, the system design should minimize the formation of sulfate. This can be addressed by ensuring the use of low sulfur fuel or by placing the catalyst in the exhaust system where the temperature of the gases can be used to minimize sulfation but still achieve emission reductions. This may require some knowledge of the vehicle's duty cycle but has been successfully accomplished in past retrofit programs.

In general, diesel fuel with low sulfur content (0.05% wt. or less) is recommended for retrofit programs. For diesel particulate filter retrofit, even lower sulfur fuel (<0.0015% wt.) will broaden the range of available technologies that can be used in a retrofit program. Lower sulfur levels may not only broaden the range of available technologies but also allow for maximum the emissions reductions from the technology selected. All catalyst-based emission control technologies benefit significantly from the use of very low sulfur fuel.

4.2 The Importance of Vehicle Maintenance

Exhaust emission controls are not a substitute for a well maintained and operated diesel engine. Engines equipped with retrofit control technologies should receive routine maintenance just as other engines would. With particularly dirty engines, periodic cleaning of a diesel oxidation catalyst or SCR catalyst might be needed. Diesel oxidation and SCR catalysts employing larger cell densities, e.g. 50 to 200 cells per square inch (cpsi), can considerably minimize the risk of plugging and fouling. For engines equipped with diesel particulate filters, backpressure should be monitored. If backpressures become excessively high, the filter should be cleaned. Fleet vehicles are often excellent candidates for retrofit because organizations that operate fleets often have strong preventative maintenance programs in place.

4.3 Matching a Retrofit Technology to an Engine Application

When deciding whether to retrofit an in-use diesel-powered vehicle with a control technology, several factors must be considered, including:

- engine size and backpressure specification,
- engine duty-cycle and resultant exhaust gas temperatures,
- fuel sulfur level,
- desired emission reductions, and
- vehicle integration.

All of these items should be discussed with the technology provider.

The size of the engine combined with its backpressure specification will allow the technology provider to properly size the retrofit control technology insuring appropriate performance while not adversely affecting vehicle operation.

The duty cycle and resultant exhaust gas temperatures are important for both catalyst and filter technologies. The performance of a catalyst is dependent on temperature and it is essential for filter manufacturers, whose system relies on the exhaust gas temperature for regeneration, to know what these temperatures will be.

Fuel sulfur level is important when considering the use of retrofit control technologies as discussed above.

The desired emissions reductions are an important consideration when choosing which retrofit control technology is appropriate. Different reductions in gaseous and particulate emissions are achieved by different retrofit control technologies. The technology chosen should reflect the targeted reductions.

Integration of a retrofit control technology on to a vehicle is also an important factor, but has been successfully accomplished in the past. A wide range of integration techniques are available to a retrofit control system design engineer including muffler replacement, in-line installation, and other techniques.

5.0 Conclusions

- Diesel emissions from mobile sources have raised health and welfare concerns, but a number of retrofit technologies exist or are being developed that can greatly reduce emissions from diesel-powered vehicles.

- Diesel oxidation catalysts, diesel particulate filters, exhaust gas recirculation, lean NOx catalysts and selective catalytic reduction have been successfully retrofitted on onroad and nonroad vehicles and these technologies offer opportunities to greatly reduce a large amounts of particulate emissions and other pollutants as well.

- Diesel oxidation catalysts can reduce particulate matter emissions from 20 to 50 percent, carbon monoxide and hydrocarbons (including toxic emissions) greater than 90 percent, and substantially reduce smoke and odor from diesel engines. Fuel sulfur levels below 0.05% wt are recommended. Lower sulfur levels improve the emission control performance of an oxidation catalyst.

- Several oxidation catalysts systems have been approved under U.S. EPA's urban bus rebuild/retrofit program along with three 0.1 g/bhp-hr systems. Another 0.1 g/bhp-hr system has been submitted for certification approval.

- Diesel particulate filter technology can reduce harmful particulate emissions by over 90 percent, reduce carbon monoxide and hydrocarbons (including toxic emissions) by over 90 percent, and significantly reduce smoke. For catalyst-based diesel particulate filters, low sulfur diesel fuel (< 15 ppm sulfur fuel) is recommended for maximum efficiency and durability.

- Both oxidation catalysts and particulate filters can be used in conjunction with biodiesel and emulsified diesel fuel blends, EGR and engine management techniques to simultaneously reduce diesel particulate and NOx emissions.

- Selective catalytic reduction can substantially and simultaneously reduce the oxides of nitrogen, particulate matter, and hydrocarbon emissions.

- Lean NOx catalysts have been combined with filter systems to provide NOx reductions of 10 to 20 percent over engine-out emissions.

- When selecting a retrofit control technology, it is important to ensure that the technology is compatible with the duty cycle of the vehicle and the desired emissions reductions.

- Properly maintained vehicles ensure retrofitted emission control technologies will perform optimally and provide carefree service.

6.0 Case Studies

The New York City Metropolitan Transit Authority (MTA), New York City, NY

Over the past two years, the New York City MTA evaluated diesel particulate filter technology on urban transit buses. The goal of the demonstration program was to show that filter technology together with low sulfur fuel can reduce diesel bus emissions to levels comparable to levels achieved by compressed natural gas (CNG) buses. The program began in February 2000 with the first ten buses entering service. A total of 50 buses were involved in the program. Emission testing will be conducted on buses with their original equipment manufacturer (OEM) muffler and standard fuel (350 ppm sulfur); their OEM muffler and low sulfur fuel (30 ppm sulfur); and with a diesel particulate filter installed and low sulfur fuel (30 ppm sulfur). Initial test results indicate the filter system achieves a greater than 90 percent reduction of HC, CO and PM. Initial test results also show PM emissions from filter-equipped buses are comparable to CNG bus PM emission levels. In April 2000, New York State pledged additional funding for the New York City MTA. The funding will be used to purchase new clean fuel buses and retrofit all of MTA's diesel-powered buses with particulate matter controls by December 31, 2003.

The Hong Kong Retrofit Program

In April 2001, the Hong Kong Department of Environmental Protection completed field tests in a pilot program to retrofit diesel oxidation catalysts on large, pre-Euro standard diesel vehicles. Fifty-nine vehicles were retrofitted. High idle tests showed that oxidation catalysts achieved an over 50 percent reduction of CO on some vehicles. Dynamometer testing using U.S. EPA procedures showed that catalysts achieved about a 36 percent reduction in PM emissions on some vehicles. Hong Kong plans to implement a voluntary retrofit program that will require the retrofit of all pre-Euro standard, diesel vehicles over four tons – about 40,000 vehicles in total – in late 2002. The voluntary retrofit program will conclude 18 months after it is started. When the voluntary program expires, retrofit of four ton, pre-Euro standard diesel vehicles will be required as part of annual vehicle license renewal. The Department of Environmental Protection estimates that their retrofit program will result in a nine percent reduction in urban vehicle particulate emissions. Because of tax incentives, only low sulfur diesel fuel (50 ppm sulfur) is available at the pump in Hong Kong.

The NYC Department of Sanitation Retrofit Project, New York City, NY

In April 2001, the New York City Department of Sanitation (NYC DOS), New York State Department of Environmental Conservation (NYS DEC), and Northeast States for Coordinated Air Use Management (NESCAUM) announced a project with Cummins Inc. to reduce particulate emissions from New York City's sanitation vehicles. Over the next three years, the collaborative project will retrofit as many as 260 refuse collection trucks with diesel particulate filters. All of the candidate trucks are powered by Cummins M11 engines. The program starts with a pilot project involving the retrofit of ten trucks. Four of these trucks will be emission tested during the spring of 2002. Retrofitted trucks will use low sulfur diesel fuel (<30 ppm sulfur).

The Central Artery/Tunnel (CA/T) Project, Boston, MA

The Central Artery/Tunnel (CA/T) Project, otherwise known as the "Big Dig", is a major highway construction project designed to reduce traffic congestion and improve mobility in central Boston. The project requires the use of heavy-duty construction equipment in a concentrated area. Under a Clean Air Construction Initiative Program, 25 percent of long-term offroad diesel equipment used in constructing the CA/T Project, will be retrofitted with advanced pollution control devices. Since the start of the retrofit program in the fall of 1998, over 100 heavy-duty engines have been retrofitted with diesel oxidation catalysts. More retrofits will be installed before the project is completed in 2004. The retrofit effort will achieve emission reductions that are the equivalent to removing 1,300 diesel buses off Boston streets for a full year.

Washington Metropolitan Area Transit Authority Bus Retrofit Project, Washington, DC

The Washington Metropolitan Area Transit Authority (WMATA), the transit company in Washington, DC, is currently implementing their Clean Fleet Initiative that involves the retrofit of their diesel bus fleet over the next two years. The initiative will take place in four stages. The first stage, the use of low sulfur diesel fuel (<30 ppm sulfur) has already been accomplished. WMATA's entire bus fleet began using ultra low sulfur diesel fuel October 1, 2001. In the second stage, WMATA will retrofit between 208 and 282 buses equipped with Cummins M11 engines with diesel particulate filters. This stage of the program will begin with a pilot program of twenty-four buses that will be retrofitted the winter of 2001/02. In the third stage, WMATA will spend about $4.6 million to retrofit mostly Detroit Diesel Corporation (DDC) powered buses in their fleet. WMATA officials believe about 926 of their 1,443 buses are good candidates for retrofit in both stage two and three of their initiative. In the last stage of their program, WMATA will use EPA grant funds to conduct a pilot program that will evaluate low-pressure exhaust gas recirculation (EGR) and diesel particulate filters to achieve both NOx and PM reductions. WMATA hopes to achieve a 40 to 50 percent NOx reduction from selected buses equipped with DDC engines.

Diesel Solutions, Seattle, WA

The Puget Sound Clean Air Agency, along with a consortium of partners, has developed the Diesel Solutions program to make diesel vehicles in Seattle region dramatically cleaner. This voluntary initiative will leverage ultra-low sulfur diesel fuel into western Washington and enable a wide range of public and private fleets to join a consortium to retrofit diesel vehicles. King County, the City of Seattle, and Boeing will immediately phase in ultra-low sulfur fuels for their transit and diesel vehicle fleets and will begin installing retrofit devices in a multi-year commitment to reduce toxic and fine particle emissions by more than 90 percent. EPA has committed to providing funding in amounts up to $2 million dollars over the next several years to leverage this project. EPA's Voluntary Diesel Retrofit Program is providing substantial grant funding and technical support to help implement the program. Other funding partners include the Puget Sound Clean Air Agency, the Washington State Department of Ecology, and EPA Region 10.

Exhibit H

U.S. Environmental Protection Agency

Voluntary Diesel Retrofit Program

Recent Additions | Contact Us | Print Version Search: GO

EPA Home > Transportation and Air Quality > Voluntary Diesel Retrofit > Technology > Verified Products

Overview
Technology
Your Fleet
Air Quality
Idling Reduction
Contacts
Latest News
Retrofit Home

Verified Products

Verified Technology List

This table shows all the diesel retrofit products that have been approved for use in engine retrofit programs. Select the manufacturer link to learn more about the retrofit kit and its potential compatibility issues. The table shows the percent reduction (of verified or tested levels) that EPA will recognize for emission reductions within state air quality plans. (Retrofit programs leading to air quality plan credits must be approved in advance.)

Key Topics: Technology

Verification Process
Testing Protocols
In-use Testing
Technical Summary
Verified Products
Cost Survey

Verified Retrofit Technologies

Manuf.	Technology	Applicability	Reductions (%)			
			PM	CO	NOx	HC
Donaldson	Series 6000 DOC & Spiracle (closed crankcase filtration system)	Highway, heavy-heavy and medium-heavy duty, 4 cycle, model year 1991 - 2003, turbocharged or naturally aspirated	25 to 32	14 to 18	0	0
Engelhard	DPX Catalyzed Diesel Particulate Filter	Highway, heavy-duty, 4 cycle, model year 1994 - 2002, turbocharged or naturally aspirated	60	60	n/a	60
Engelhard	CMX Catalyst Muffler	Heavy Duty, Highway, 1989-1993 model year, 2 cycle engines	20	40	n/a	50
Engelhard	CMX Catalyst Muffler	Heavy Duty, Highway, 1989-1993 model year, 4 cycle engines	20	40	n/a	50

©H-76

Engine Control Systems	AZ Purimuffler	Heavy Duty, Highway, 1989-1993 model year, 2 cycle engines	20	40	n/a	50
Engine Control Systems	AZ Purimuffler	Heavy Duty, Highway, 1989-1993 model year, 4 cycle engines	20	40	n/a	50
Johnson Matthey	Continuously Regenerating Technology (CRT) Particulate Filter	2 & 4 cycle, model year 1994 - 2002, turbocharged or naturally aspirated engines	60	60	n/a	60
Johnson Matthey	CEM Catalyst Muffler	Heavy Duty, Highway, 1989-1993 model year, 2 cycle engines	20	40	n/a	50
Lubrizol	PuriNOx Water emulsion fuel	Heavy Duty, Highway & Non-road, 2 & 4 cycle	16 to 58	-35 to 33	9 to 20	-30 to -120
Various	Biodiesel (1 to 100%)	Heavy Duty, Highway, 2 & 4 cycle	0 to 47	0 to 47	0 to -10	0 to 67

[Diesel Retrofit: Glossary | Site Map]

About Office of Transportation and Air Quality | Definitions | What are Mobile Sources? | Related Internet Resources | Free Viewers and Readers

EPA Home | Privacy and Security Notice | Contact Us

Last updated on Monday, May 12th, 2003
URL: http://www.epa.gov/otaq/retrofit/retroverifiedlist.htm

Exhibit H

©H-77

Diesel Technology Forum

Retrofit Activity Matrix

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
ARCO Tanker Truck Demonstration / BP ARCO ECD Demonstration Program	Chuck LeTavec, BP (714) 670-5021 letavca@bp.com	29 1995-1996 Kenworth Class 8 Fuel Transport Trucks	Cummins M11 Turbocharged 10.8 liter 330 hp	ECD-Only (9); CARB diesel-Only (10); Johnson-Matthey CRT Filters (5) and Engelhard DPX filters (5)	Yes, both CARB diesel and ECD.			BP
CALTRANS – California Department of Transportation, "Clean Air Initiative"	"The Green Team"DOT, Equipment Department:Rick Sheasby(916) 227-9600Kris Teague(916) 227-9669kris.teague@dot.ca.govLook for news about Initiative to be posted:www.dot.ca.gov	DOT wants to evaluate for implementation technologies that will help clean the air. For example, 48 18,200 lb freeway sweepers with dust particulate suppression. Or	14,000 vehicle fleet with range of vehicles, engine types and years. Some targeted engines include:Navistar DT 446; and Cummins M11, B and C	Eventually, hope to use ULSD in entire diesel portion of fleet. (Approximately 38%)Once ULSD is in place, particulate traps / catalysts will be installed on many vehicles. Other emission control devices	Yes, 15 ppm in some vehicles, not yet in all. Implemented use of ULSD in over 22 sites – continuing		January:Avg. High – 68°FAvg. Low – 49°FJuly:Avg. High – 84°FAvg. Low – 65°F	State.

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
		6 15,300 lb 2-ton cargo trucks that have been retrofit with exhaust aftertreatment. Several strategies being explored including Hybrids, solar, and bi-fuels.	series, and N14s.	being considered, including EGR retrofits and various technology combinations. Also interested in trying fuel to reduce NOx.	expansion.			
CARB Lower Emission School Bus Program – Bus Replacement and Bus Retrofit Programs	Earl Landberg(916) 323-1384www.arb.ca.gov/msprog/schoolbus/schoolbus.htm	Approximately 1,900 diesel school buses in school districts throughout California are eligible for CARB retrofit funds.	CARB has verified several types of engines for use with traps in the Bus Retrofit Program, including Cummins, Caterpillar and Detroit Diesel. See http://www.arb.ca	Bus Replacement Program funds new green diesel buses with 3 g/bhp NOx.Bus Retrofit Program funds particulate traps, Englehard DPX and Johnson Matthey CRTs.	In use in California, but not associated with this program.		January:Avg. High – 68°FAvg. Low – 49°FJuly:Avg. High – 84°FAvg. Low – 65°F	$16 million appropriated by California legislature, dolled out by CARB.

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
			.gov/diesel/documents/verifieddevices.htm for a complete listing.					
CARB Urban Transit Bus Fleet Rule	Nancy Steele (626) 350-6598www.arb.ca.gov/msprog/bus/bus.htm	HDD Urban Transit buses.	Transit rule requires PM trap retrofits on 100% of pre-1991 engines, and majority of 1991-1995 engines by 2003. See http://www.arb.ca.gov/diesel/documents/verifieddevices.htm for a complete listing of engines and approved retrofits.	Rule imposes minimum NOx fleet average emissions requirements and PM retrofit technology requirements.	ULSD required, where available, as part of the Transit Rule.		January:Avg. High – 68°FAvg. Low – 49°FJuly:Avg. High – 84°FAvg. Low – 65°F	Compliance with rule is mandatory.
City of Seattle, WA Municipal Fleet Program	David S. Kircher, Puget Sound Clean Air Agency (206) 689-4050;	HDD municipal vehicles, including utility		Switch to ULSD, supplied by Tosco Refining (Union	ULSD, 15 ppm.		January:Avg. High – 45°FAvg. Low –	EPA OTAQ grant (VDRP). EPA committed

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
	davek@pscleanair.orgEPA, OTAQ, Anthony Erb, erb.anthony@epa.gov EPA, Region 10 Air Quality Office, Wayne Elson, elson.wayne@epa.gov	trucks and dump trucks.		76), in 2001.Begin retrofitting fleet in 2001, to be completed by 2003.Will use primarily PM filters and oxidation catalysts.			35°FJuly:Avg. High – 75°FAvg. Low – 55°F	to provide $2 Million overall.
Everett, Washington Clean Diesel School Bus Retrofit Demonstration Project – *Sponsors* include: Puget Sound Clean Air Agency, WA Dept. of Ecology, and EPA Region 10.	Paul Carr, Puget Sound Clean Air Agency (206) 689-4085davek@pscleanair.orgEPA, Office of Transportation and Air Quality, Anthony Erb, erb.anthony@epa.gov EPA, Region 10,Wayne Elson, elson.wayne@epa.gov	25-30 HDD school buses in Everett Fleet will be selected and retrofitted.	Models of buses include DTA 360; Cummins B Series; and Caterpillar 3126 B. Models and years are yet to be determined.	To be determined.	Yes, ULSD beginning Sept. 2001. ULSD supplied by Tosco Refining (Union 76).		January:Avg. High – 45°FAvg. Low – 35°FJuly:Avg. High – 75°FAvg. Low – 55°F	EPA OTAQ grant (VDRP). EPA committed to provide $2 Million overall.
Ground Freight Partnership Program – *Sponsored* by EPA, new program to be announced in January 2002.	Jennifer Dolin,EPA OTAQ,(202) 564-9073	All diesel freight trucks. Under program, carriers who meet certain performance goals for CO,	Would apply to any engine.	Carriers could use EPA verified technology, or any other technology to achieve performance goals.	ULSD would be an accepted form of technology		Nation wide.	Voluntary incentive program.No funding provided.

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
		PM and NOx would receive Voluntary Green Transportation Brand Label similar to EPA "Energy Star" program.						
Hartsfield International Airport, Atlanta, GA,"Fifth Runway Project," Construction Emission Reduction Program	L. Carrol Bryant, Senior Project ManagerEnvironmental Science Associatescbryant@esassoc.com(727) 572-5226Dr. Tom NissalkeDirector, Environmental & Technical Services, Department of AviationHartsfield Airport(404) 209-3175	Construction equipment, including water pumps, bulldozers, excavators, rollers and other HDD vehicles. Contractors must specify equipment in bids; cost-effective analysis used to determine best emission reduction opportunities.	Large range of engines and years, including:Caterpillar; Isuzu; and Volvo engine types.	As of Oct. 2001, Airport has 2 small construction projects, which will be incorporating various NOx reduction technologies, including oxidation catalysts.Airport will also consider PM reduction devices and fuel additives such as PuriNOx.	No.		January:Avg. High - 50°FAvg. Low - 31°FJuly:Avg. High - 88°FAvg. Low – 69°F	Program coordinated through EPA and Georgia Environmental Protection Division.State funds cost-effective analysis.

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
Hertz Equipment Service Fleet - Los Angeles, CA / BP ARCO ECD Demonstration Program	Chuck LeTavec, BP(714) 670-5021, letavca@bp.com	20 Medium-duty flatbed-type trucks in Hertz Service Fleet.	1997 and 1999 Ford F-250, 450, and 550	5 vehicles CARB diesel-only;5 vehicles with Johnson Matthey CRTs; 5 vehicles with Englehard DPX filters; and 5 vehicles with ECD	Yes, both CARB diesel fuel and ECD.		January:Avg. High - 67°FAvg. Low – 48°FJuly:Avg. High - 84°FAvg. Low - 64°F	
Houston, TX NOx Reduction Program – Diesel Demonstration Project	Steve Dornak, Administration Manager,Clean Air Team,City of Houston(713) 837-9635www.ci.houston.tx.us/citygovt/mayor/diesel.pdf ORwww.ci.houston.tx.us/citygovt/mayor/cleanair.pdf	Over 2800 HDD vehicles in City fleet. City has tested 27 vehicles, and will retrofit 5 more by end of October 2001. Vehicles include road sweepers, grade-alls and dump trucks.	Retrofit technology installed on HDD vehicles over 50 hp including: Elgen Roadsweeper 110 hp; Volvo SideLoader 275 hp; Heavy Vacu-truck with Cummins 350 hp; and 1992 and 1994 International Grade-Alls.	City testing various NOx control technologies under real-world conditions, including diesel emulsion fuels such as PuriNOx, catalytic converters, oxidation catalysts and novel NOx control technologies from Johnson Matthey, Englehard, and Exengine (in conjunction with	No.		January:Avg. High – 61°FAvg. Low – 42°FJuly:Avg. High – 92°FAvg. Low – 74°F	CMAQ funding for fuel testing ($89,000).EPA grant money for testing retrofit devices (~$550,000).Remaining funding from City of Houston, possibly from Senate Bill 5.

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
				Clean Air Systems).				
Idle Reduction Program – *Sponsored* by EPA	Paul Bubbosh,EPA VDRP,(202) 564-9322	Program applies to diesel trucks (particularly Class 8 Long Hauls), locomotives and marine engines.	All engines.	Idle reduction program focuses on idle control technology, including Auxilliary Power Units, and Electrification. Program may also consider engine modifications by Cummins and Detroit Diesel.	No.			Not yet funded. Most likely, EPA will issue grants for demonstration projects.
King County, WA Fleet Program	Jim Boon (206) 684-1498Jim.Boon@METROKC.GOV;Paul Carr, (206) 689-4085davek@pscleanair.orgEPA, Office of Transportation and Air Quality, Anthony Erb, erb.anthony@epa.gov EPA, Region 10 Air Quality Office, Wayne Elson,	Transit HDD bus fleet (1,100 vehicles) and other fleet vehicles.	Cummins M-11; Cummins C8.3	Immediately, switch to ULSD, supplied by Tosco Refining.Equip 800 buses, by 2003, with retrofit devices to reduce emissions.Require ULSD and emission control devices in new vehicle and equipment	ULSD used in all 1,100 vehicles of bus fleet (15 ppm).		January:Avg. High – 45°FAvg. Low – 35°FJuly:Avg. High – 75°FAvg. Low – 55°F	EPA OTAQ grant (VDRP). EPA committed to provide $2 Million overall.

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
	elson.wayne@epa.gov			purchases.				
Los Angeles City Sanitation Fleet / BP/ARCO ECD Demonstration Program	Chuck LeTavec, BP (714) 670-5021, letavca@bp.com	15 Peterbilt refuse haulers and Kenworth T-800 dumptrucks in pilot. Fleet includes a total of 650 city-owned vehicles servicing Sunshine Canyon Landfill.	Cummins ISM 305V (haulers); Cummins ISM370 (dumptrucks)	ULSD required, plus gradual retrofit of fleet with particulate filters.Testing 15 vehicles as part of the ECD Demonstration Program: 5 CRTs, 5 DPXs; 2 on ECD; and 3 on ULSD.	Yes, both CARB diesel fuel and ECD.		January:Avg. High - 67°FAvg. Low - 48°FJuly:Avg. High - 84°FAvg. Low - 64°F	Bureau of Sanitation, City of Los Angeles, with assistance from EPA VDRP
Los Angeles, CA – Metropolitan Transit Authority / BP/ARCO ECD Demonstration Program	Chuck LeTavec, BP (714) 670-5021, letavca@bp.com	20 1998 New Flyer Low-floor 40 foot buses.	DDC Series 50, MY 1998	8 vehicles with ULSD only;2 vehicles with Johnson Matthey CRTs; 2 vehicles with Englehard DPX filters; and8 vehicles with ECD	Yes, both CARB diesel fuel and ECD.	City and Suburban Bus Route	January:Avg. High – 67°FAvg. Low – 48°FJuly:Avg. High – 84°FAvg. Low – 64°F	
Los Angeles, CA – School Districts:	Chuck LeTavec, BP (714) 670-5021, letavca@bp.com	HDD school buses.	Various	ECD, DPX & CRT	Yes.		January:Avg. High - 67°FAvg. Low - 48°FJuly:Avg. High - 84°FAvg.	BP Helios to donate $1 Million to 8 Southern CA school districts

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
							Low - 64°F	for CRTs and DPX's.
Manchester, NH Airport Retrofit Program	Manchester Airport, Dick Fixler, (603) 624-6539; Coralie CooperNESCAUM (617) 367-8540 ccooper@nescaum.orgEPA Region 1, Pete Hagerty, (617) 918-1049hagerty.peter@epa.gov	30 airport ground support HDD vehicles, including snow and dump trucks that are in constant use.		Retrofit catalytic converters to reduce NOx.	No.		January:Avg. High – 31°FAvg. Low – 9°FJuly:Avg. High – 81°FAvg. Low – 58°F	Currently, program lacks funding and is on hold.
Massachusetts Bay Transportation Authority (MBTA) Bus Retrofit Program	Ann HurtzenbergChief Operating OfficerMBTA(617) 222-3150	Out of a 980 bus fleet, MBTA overhauling and/or retrofitting 400 newest diesel buses (1994-94) with new engines, ULSD and particulate filters.	All 400 1994-1995 (4 cycle Series 50 Detroit Diesel engines) being replaced with "Reliabuilt" Detroit Diesel 1999 engines. Original NOx 5.0 g/bhp-hr → new 4.0 g/bhp-hr; original PM	In addition to new engines in 400 newest buses, MBTA using ULSD and testing particulate filters. Test program on 50 buses to begin in December 2001. 25 buses with Johnson Matthey CRT and 25 with Englehard DPX.	As of Sept. switched to ULSD at 2 locations, total of 45% of the fleet.		January:Avg. High – 36°FAvg. Low – 22°FJuly:Avg. High – 82°FAvg. Low – 65°F	MBTA funding retrofit demonstration. Mixture of state and federal capital funds for engine replacements and ULSD.

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
			0.07 → 0.05 g/bhp-hr.					
Massachusetts Clean Air Construction Initiative / "Big Dig" Pilot Project	Clean Air InitiativeMass DEP,Steve Lipman(617) 292-5630;Massachusetts Turnpike Authority Alex Kasprak(617) 556-2462 www.bigdig.com; NESCAUM: Heavy-Duty Engine Workgroup; EPA Region 1, Pete Hagerty,(617) 918-1049 hagerty.peter@epa.gov	Mass Clean Air Initiative will retrofit over 120 HDD vehicles, including 50-70 construction vehicles associated with the Big Dig highway project such as: front-end loaders; bulldozers; backhoes; cranes; air compressors and excavators.	Engines include Caterpillar, Mantis Cranes, Deere and Nichi.Under Clean Air Initiative **all** future contractors must retrofit construction vehicle engines with oxidation catalysts.	Vehicles retrofit with oxidation catalysts to obtain reductions in PM (3 tpy), HC (5 tpy) and CO (25 tpy).Also trying emulsion fuel additives.Currently , testing 10 vehicles to determine emission reductions.	No.		January:Avg. High – 36°FAvg. Low – 22°FJuly:Avg. High – 82°FAvg. Low – 65°F	State Highway Department and Mass Turnpike Authority have $50,000 to provide 50% matching funding to contractors to purchase emission control devices.After that, contractors must cover costs.
Navy Landing Craft – Non-Aftertreatment Pilot Project – US Navy; EPA; MARAD	Jonathan DeHartDiesel Engine Technical SpecialistEngine and Power Transmission Branch NAVSEA - Philadelphia, NSWCCD	Marine diesel vessels.Pilot testing phase Fall 2001.	Pilot will target high-speed Detroit Diesel 2-stroke naturally	-Catane DFA Fuel Upgrade (ferrocene fuel additive)-Clean Cam Technology System-Continuous Water Injection			January:Avg. High – 37°FAvg. Low – 22°FJuly:Avg. High – 86°FAvg. Low – 67°F	EPA grant.Seeking additional sponsorship.

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
	(215) 897-7698;dehartjc@nswccd.navy.mil		asperated marine engines (DDC Series 71 - 12V-71N) (MY early 1980-90s).	(post-compressor water injection)-ECOTIP Superstack Fuel Injector (small sac volume injector)				
NESCAUM Salem Harbor Power Plant Construction Equipment Retrofit Pilot Project	Coralie Cooper, NESCAUM (617) 367-8540 ccooper@nescaum.org	Construction vehicles were equipped with pollution control devices and tested under real world conditions.	5 vehicles: one International dump truck, two front-end loaders (Caterpillar and Volvo), one Caterpillar backhoe and one International bulldozer.	Four types of retrofit technologies tested: oxidation catalysts, fuel borne catalyst, active particulate filter and passive particulate filter. Project goal to determine ability of technologies to reduce PM, HC and NOx emissions in off-road equipment.	No.		January:Avg. High – 36°FAvg. Low – 15°FJuly:Avg. High – 82°FAvg. Low – 61°F	Collaborative effort by NESCAUM, US Gen Co., EPA, Manufacturers of Emission Control Association (MECA), and Massachusetts DEP.
New Jersey DOT/DEP Retrofit Evaluation Program	NJDOT, Don Borowski609-530-6505DonBorowski@dot.state.nj.us; NJ DEP, Ralph Bitter609-530-	HDD public fleet vehicles are being evaluated for retrofit opportunities,	Older diesels in the 7.6L to 14L range, including International,	Retrofit of older vehicles being evaluated, several technologies being considered,	Possibly.	State is interested in matching technologies/fuels to vehicle duty	January:Avg. High – 40°FAvg. Low – 21°FJuly:Avg. High – 85°FAvg.	CMAQ funding provided, subject to FHWA oversight. DOT

Exhibit I

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
	4113rbitter@dep.state.nj.us	including construction equipment and school buses.Prior catalytic converter program put on hold while EPA conducts tests on technology.	Cummins and Detroit Diesel.	including oxidation catalysts, particulate traps, biodiesel, fuel additives and ULSD. Also considering idle reduction strategies		cycles.	Low – 65°F	administering funding.
New York City Department of Sanitation (DOS) Garbage Truck Research & Development Project – NYDOS, NESCAUM, and Cummins w/ NYS DEC peer review.	David Park, NESCAUM (617) 367-8540dpark@nescaum.org	10 low-entry, dual-steer, rear-loading diesel refuse collection trucks. Project goal, all trucks in fleet with Cummins powertrains will be retrofitted (~260 garbage trucks).	All Cummins Engines.The first ten are 1997, Cummins M-11 (280e) engines in Series 25 CF trucks, with Crane chassis, and Heil body.	5 [Johnson Matthey] CRT PM filters and 5 [Engelhard] DPX PM filters.	During test phase, 30 ppm ULSD from RAD Energy will be used.		January:Avg. High – 38°FAvg. Low – 25°FJuly:Avg. High – 84°FAvg. Low – 68°F	$3.15 Million over 4 years: ½ from Cummins (through consent decree); other ½ through cost share from project participants.
New York City Transit (NYCT)	Lowell, Dana dalowel@nyct.comJohnson Matthey, (610) 341-	Urban fleet of 4,000 HDD transit buses.	Johnson Matthey CRTs will first be	Purchase new diesel hybrids – 140 by 2002, 340 by	ULSD, 30 ppm.		January:Avg. High – 38°FAvg. Low –	NY State Environmental Bond Act

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
Clean Diesel Vehicle Project	8300www.matthey.com;NYCT http://www.mta.nyc.ny.us/ New York State DEC: http://www.dec.state.ny.us/;Dr. Thomas Lanni trlanni@gw.dec.state.ny.us		used on Series 50 post-1993 models, then diesel hybrids and all new diesels, then entire fleet.Demonstration study of CRTs on 50 buses from 2001-2002.	2003.Use ULSD, 30 ppm, for entire fleet.Retire all 2-stroke engines by 2003.Retrofit buses with Johnson Matthey CRTs – 250 by 2002, entire fleet by 2003.Emissions of PM, HC, CO and NOx will be reduced and are currently being studied and quantified.			25°FJuly:Avg. High – 84°FAvg. Low – 68°F	provides $1 Million to NYCT to test CRT retrofit technology. Project partners include Johnson Matthey, NYCT, Corning International, NYSDEC, Environment Canada, Equilon, and RAD Energy Corporation.
Northern Arizona University, Flagstaff, AZ; Idling Emission Control Workshop – *Sponsored* by EPA	Paul Bubbosh, EPA VDRP,(202) 564-9322bubbosh.paul@epa.gov orwww.epa.gov/otaq/retrofit	HDD trucks, buses (including tour buses).	Workshop applies to all HDD vehicles that frequently idle.	Workshop demonstrating the use of idle-control technologies to obtain up to 90% reduction in CO2 and reduce visible smoke in national parks.	No.		January:Avg. High – 42°FAvg. Low – 15°FJuly:Avg. High – 81°FAvg. Low – 50°F	EPA, Arizona DEP.
Pennsylvania,	Chris Trostle, PA	HDD school	To be	To be selected	Possibly, if		January:Avg.	3M Corp. to

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
Department of Environmental Protection; 3M Corporation Diesel School Bus Retrofit Demonstration Project	DEP,(717) 787-9494www.dep.state.pa.us	buses in urban areas. Application accepted until June 29, 2001. Fleet to be chosen Fall 2001.	determined.	based on the severity of the pollution in area, model engines and other characteristics of fleet. Primarily considering particulate traps and ULSD.	funding available.		High – 34°FAvg. Low – 19°FJuly:Avg. High – 83°FAvg. Low – 62°F	contribute $200,000 to program. EPA to contribute $50,000. PA DEP to pay school districts 100% of costs for retrofit technology.
Port of Houston Pilot Retrofit Program	Port of Houston Authority, http://www.portofhouston.com; Bruce Anderson,Port of Houston,(713) 789-2213;EPA NVFEL, Mark Coryell, (734) 214-4446, coryell.mark@epa.gov	50 to 250 vehicles: primarily yard hustlers, cranes and rubber tired gantries.	To be determined.	Retrofitting between 50-250 vehicles with oxidation catalysts, SCR technology and/or fuel additives (PuriNox and SINOx) to reduce NOx emissions by 80-90% and PM emissions by 20-30%.	PuriNOx and SINOx low emission diesel fuels / additives.		January:Avg. High – 61°FAvg. Low – 42°FJuly:Avg. High – 92°FAvg. Low – 74°F	Currently funding comes from CMAQ.EPA OTAQ is assisting Houston in obtaining SIP credits for this program.
Portland, OR Tax Incentive Programs – Pollution Tax	Pollution Tax Credit Program,Kevin Downing, Oregon	Pollution Tax Credit applies to retrofit projects	Unknown – DEQ has not yet received	Diesel emission control devices that are verified by	Proposed revisions to		January:Avg. High – 45°FAvg. Low –	Oregon state legislature.

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
Credit Program & Business Energy Tax Credit Program	DEQ,(503) 229-6549Business Energy Tax Credit Program,Mark Kendall,Office of Energy,(503) 378-6043www.deq.state.or.us/wq/taxcredits/txcp.htm	for highway and off-road diesel engines that are eligible for income tax credit certificate up to 50% of capital investment for pollution control.	any applications for credits.	EPA.	Business Energy Tax credit would apply credits to fuels such as ULSD and PuriNOx.		33°FJuly:Avg. High – 79°FAvg. Low – 56°F	
Ralph's Grocery Company / BP /ARCO ECD Demonstration Program	Chuck LeTavec, BP (714) 670-5021, letavca@bp.com	20 1999 Sterling L-Line (Class 8) HDD Delivery Trucks (Model AT9513 Tractors).	1999 Detroit Diesel Series 6012.7 L turbocharged diesel, 430 hp	CARB Diesel-only (5);Johnson-Matthey CRTs (5) and Englehard DPX (5); ECD-only (5)	Yes, both CARB diesel fuel and ECD.		January:Avg. High – 68°FAvg. Low – 49°FJuly:Avg. High – 84°FAvg. Low – 65°F	
San Diego School Bus Retrofit Demonstration Program / BP ARCO ECD Demonstration Program	San Diego School Bus Program, School District Office, Roger Hensen, (858) 496-8468; Chuck LeTavec, (714) 670-5021, letavca@bp.com Jack Kitowski, CARB	30 1998 American Transportation 3000 RE buses with International chassis; 32,200 lb test weight	International 530 E 8.7 L, I6 turbo, 275 hp.	30 school buses will be used as demonstration program.Retrofit technologies include: ULSD, EC Diesel Fuel (ECD), Johnson Matthey CRTs.	Yes, both CARB diesel fuel and ECD.		January:Avg. High – 65°FAvg. Low – 48°FJuly:Avg. High – 76°FAvg. Low – 65°F	Federal and State funding,

Diesel Technology Forum

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
Texas Emission Reduction Plan (TERP) – Senate Bill 5	Bill Jordan, TERP coordinator, 512/239-2583wjordan@tnrcc.state.tx.uswww.tnrcc.state.tx.us/oprd/sips/terp.html	All on- and off-road diesel vehicles and equipment will be eligible for new incentive plan.Project to be implemented in Fall 2001.	All capable of being retrofitted for NOx emission reduction technology.	To receive funding must utilize reduction technology that achieves 30% reduction in NOx emissions AND is cost-effective (i.e., less than $13,000 per ton reduced).	Yes, it will be covered by incentive program.		January:Avg. High – 61°FAvg. Low – 40°FJuly:Avg. High – 93°FAvg. Low – 72°F	Senate Bill 5 provides $130 Million/year for retrofit incentives.Private and public entities or individuals apply for grants from the Texas Natural Resource Conservation Commission (TNRCC).

Program Sponsor / Location	Contacts	Equipment Application / Vehicle Type	Engine Model/Year	Retrofit Technology (NOx /PM strategy; % emissions reduction)	Use of Low Sulfur Fuel	Duty-Cycle(flow-rate; exhaust gas temp.; engine out emissions)	Climate	Funding Source
Washington Metro Area Transit Authority (WMATA) Retrofit Program	Phil WallaceWMATA(202) 962-5687Harpal Kapoor, hkapoor@wmata.com;EPA, OTAQ:Jim Blubaugh, blubaugh.jim@epa.gov	Entire fleet (1,400 buses) will use ULSD.Particulate filters will be placed on majority of fleet in few years.	Detroit Diesel Series 50 engines, and Cummins L10 and M11 engines.	Project includes purchase and installation of Johnson Matthey CRT and Englehard DPX on 900+ buses to reduce PM emissions; and introduction of ULSD for entire fleet.	ULSD, 15 ppm instituted for entire fleet on October 2001.		January:Avg. High – 42°FAvg. Low – 26°FJuly:Avg. High – 88°FAvg. Low – 71°F	$1.9+ Million due from Cummins for CRTs and other retrofits;$2 Million expected from Virginia CMAQ for future retrofits.

GLOSSARY:"CMAQ" – Congestion Mitigation Air Quality Improvement Program, through the Federal Highway Administration"CO" – Carbon Monoxide"CO2" – Carbon Dioxide"CRT" – Continuous Regenerating Technology by Johnson Matthey that filters out PM"DEP" – Department of Environmental Protection"DPX" – Diesel Particulate Filter by Englehard that filters out PM"ECD" – Emission Control Diesel, a BP Amoco product"EPA OTAQ" – Environmental Protection Agency's Office of Transportation and Air Quality"FHWA" – Federal Highway Administration"HDD" – Heavy Duty Diesel"NOx" – Nitrogen Oxides"PM" – Particulate Matter"SCR" – Selective Catalytic Reduction technology"tpy" – tons per year"ULSD" – Ultra Low Sulfur Diesel Fuel"VDRP" – EPA's Voluntary Diesel Retrofit Program

CHAPTER **14**

SUMMARY AND CONSIDERATIONS FOR EVALUATING FUELS AND VEHICLE TECHNOLOGIES

14.1 SOME CONCLUSIONS REGARDING FUEL CHOICES

14.1.1 Diesel Engines

Diesel will remain the standard fuel for transit for at least another decade. Diesel engines offer superior fuel efficiency, which will not likely be exceeded until direct hydrogen fuel cell buses are commercialized. Advances in diesel engine emission control technology will ensure that diesel engines will be commercially available at least through the year 2010. Post-2004 diesel engines will emit NO_x below 2.5 g/bhp-hour (50 percent of the 1997 standard) with PM at 0.05 g/bhp-hour (current standard). Diesel fuel offers the lowest fire hazard of any of the fuels considered here for transit buses. Fire protection systems in vehicles, fueling facilities, and maintenance garages can therefore be considerably less elaborate and less costly than those needed with other, more volatile, fuels.

14.1.2 Hybrid-Electric Propulsion

Hybrid electric is a very promising technology for the next generation of transit buses. Suitable propulsion motor and power control system designs are becoming increasingly available. Modern AC propulsion motors controlled by electronic inverters are inherently reliable and durable and allow most of the vehicle braking to be accomplished dynamically (electrically), with no mechanical wear. Maintenance costs for transmission and brake repairs in conventional transit bus fleets are substantial and could be greatly reduced by converting to electric-drive trains. With a suitable energy storage device for capturing braking energy and augmenting engine power during acceleration, a substantially smaller engine may be used. A compact, lightweight energy storage device that will charge and discharge with the necessary power has not yet been perfected. Batteries may be used in the near term. Using a properly rated diesel engine in a hybrid-electric bus, energy consumption and emissions will be 30 to 40 percent lower than current baseline. Additional NO_x and PM emission reductions could be realized by using alternative-fuel engines in hybrid-electric buses, instead of diesel.

14.1.3 Methanol and Ethanol

The available emission data show that alcohol-fueled buses generally exhibit substantially and consistently lower NO_x emissions than diesel buses. However, no alcohol engine is currently certified for heavy-duty vehicles. The only commercialized alcohol engine, the 6V-92, is no longer offered as an automotive engine, even for diesel fuel. The LACMTA, the transit agency operating the largest fleet of methanol (and subsequently, ethanol) buses, has experienced significantly higher maintenance costs and reduced engine life with their alcohol-fueled buses compared with diesel baseline. Fuel cost per unit of heating value for both methanol and ethanol have remained substantially higher than that of diesel over the past decade (readers should refer to the cost model, *FuelCost 1.0,* for illustrations). The Energy Information Agency projects that diesel fuel supplies and price should remain stable for at least another decade; there appears to be little reason to believe that the price competitiveness of alcohol fuels will improve any time soon. This fundamentally limits the market potential for alcohol fuels at present and effectively prevents the investment needed to engineer a current engine model to alcohol.

14.1.4 CNG

CNG is the best-established alternative fuel for transit. Vehicles and fueling stations are commercially available from numerous vendors. Compared with diesel, CNG fuel offers significant NO_x reductions and moderate PM reductions. However, the emission performance of CNG buses is quite sensitive to fuel system calibration. Chassis-dynamometer emission data document many instances of excessively high NO_x emission rates from CNG buses. This problem will likely be substantially eliminated with emerging electronic fuel metering systems. These systems use sensors and feedback controls to reliably maintain lean air/fuel mixtures and can clearly achieve NO_x rates as low as 1.5 g/bhp-hour. In many regions, using CNG will yield savings in fuel bills of 30 to 35 percent, compared with diesel. However, other operating costs exist with CNG that more than offset the savings in fuel costs. These include electric power and maintenance costs for the compressor station and higher vehicle maintenance costs. Total operating costs for CNG buses will usually moderately exceed those for diesel. For a typical 200-bus transit division, it is estimated that median fuel-related operating costs will be \$0.66 per mi with CNG and \$0.62 per mi with diesel. Incremental capital costs for CNG buses are substantial, and there is no evidence to indicate that these will decrease in the future. Two major factors account for CNG buses' inherently higher cost: (1) the high precision needed to engineer and manufacture light, durable, and reliable onboard CNG tanks as well as the liability cost associated with defects in tank design and manufacture; and (2) the need for onboard fire protection systems. Whereas fueling station installation and garage modifications for CNG represent substantial up-front costs, the long life of these investments greatly reduces their life-cycle cost impact compared with incremental vehicle replacement costs. (Refer to the cost scenarios appearing in *FuelCost 1.0 User's Guide* for examples.)

14.1.5 LNG

LNG is emerging as a nice alternative to CNG. It offers more consistent fuel quality than pipeline gas, lower onboard storage weight and volume, and a substantially lower pressure hazard. Although LNG tanks are extremely well insulated, heat transfer into the tanks is unavoidable. Operationally, this means that fuel vaporization and weathering limit fuel storage time onboard the vehicle, which makes LNG operationally more rigorous than CNG. LNG fuel system designs are also not as mature as those for CNG. In most parts of the country, LNG fuel is more costly than CNG, even if the cost of compression work is included with that of procuring CNG.

14.1.6 LPG

LPG buses have demonstrated reliable operating performance and good safety records in the past. For example, the CTA operated much of its bus fleet on LPG for many years. Chicago's LPG operations were ultimately ended by the lack of a suitable commercially available engine. The recent certification of the LPG version of the Cummins B5.9 engine, however, makes LPG a much more practical option for small- to medium-sized transit buses; however, a commercialized OEM heavy-duty 8- to 10-L LPG engine must become available for LPG to make any significant inroads into the full-sized transit bus market.

The fuel storage weight and volume associated with LPG are only somewhat greater than those associated with diesel. LPG fuel tanks are designed for the same working pressures as LNG; pressure hazards are accordingly similar. However, because LPG is stored at ambient temperature, it can be stored onboard indefinitely without venting or weathering. Being designed for moderate storage pressures and having no need for insulated tanks, LPG fuel systems are substantially less expensive than CNG and LNG fuel systems. Limited vehicle procurement experience indicates that this results in bus purchase prices \$10,000 to \$20,000 lower than those of similar CNG or LNG models. On the other hand, LPG has a lower octane rating than natural gas. Therefore, the brake-specific fuel consumption will be poorer than with CNG/LNG because of the reduced compression ratio needed to prevent combustion knock. Also, LPG fuel costs are typically higher than those for CNG and LNG and are subject to greater seasonal and regional price fluctuations. However, the cost of LPG fueling facilities is moderate, and facility design standards are well established. Maintenance and operating costs for LPG fueling facilities are similar to those for diesel fuel. The emissions performance of LPG engines should be comparable to those of CNG/LNG engines. LPG presents an arguably greater fire hazard than CNG or LNG. Like gasoline, LPG fuel leaks produce vapor that is heavier than air. The dense vapor remains concentrated near ground level and tends to spread laterally over a large area where it may encounter ignition sources. This contrasts with LNG or CNG leaks, which are buoyant in air once they have warmed up to ambient temperatures, and thereby mix with air more readily, and more quickly become diluted to subflammable concentrations. Numerous LPG fleets have documented years of safe operations, but managers need to know and enforce appropriately rigorous facility design standards and operating procedures.

In summary, LPG offers a potential emissions performance similar to that of CNG and LNG but with operational characteristics more similar to those associated with conventional liquid fuels and with lower vehicle and fueling facility costs.

14.1.7 Fuel Cells

The first commercialized fuel cell bus will most likely use PEM fuel cells directly fueled with compressed hydrogen gas. Such a bus will be a true zero-emission vehicle with excellent performance, acceptable range, and good maintainability and will have superior fuel utilization efficiency. It will probably be offered at twice the price of a similar diesel bus. The introduction of fuel cell engines will be facilitated by the prior commercialization of hybrid-electric motor buses, because the electric propulsion motors and power control and distribution systems for hybrid electric buses are very similar to those for fuel cell buses. Onboard reformers are now being developed that appear to be practical for operating fuel cells with methanol but that will have nonzero emissions. Currently, the distribution system for hydrogen fuel is quite limited. Compressed hydrogen has substantially lower energy density than CNG. The hydrogen molecule is quite small, giving the fuel a remarkable propensity to leak through fittings and seals. These properties add cost and complexity to the distribution and storage of hydrogen as compressed or liquefied hydrogen gas. *Fuel island* *reformers* could be developed, which would allow stored diesel or methanol, or pipeline natural gas, to be used as a feedstock for hydrogen gas and may offer a more practical fuel supply scenario than distribution and bulk storage of compressed or liquefied hydrogen gas. Hydrogen leaks are a serious concern, as the gas is quite buoyant and explosive; appropriate design standards for maintenance garage fueling facilities do not yet exist.

14.2 CONSIDERATIONS FOR EVALUATING FUEL OPTIONS AND CONVERTING A TRANSIT BUS OPERATION TO ALTERNATIVE FUELS

As evidenced by the case studies presented in Chapter 13, a number of transit agencies are successfully operating on alternative fuels. Some conversion programs have been much more difficult than their planners envisioned. From these experiences, it is clear that much can be done during the process of planning and executing the conversion to alternative fuels to facilitate success.

1. Evaluate the local situation candidly and thoroughly. Converting to an alternative fuel will entail costs and operational changes that do not have to be borne with continued operation on diesel. What benefits will be realized in converting to the alternative? Emission reductions and fuel-source diversification are the most commonly cited reasons for considering alternatives to diesel. What is the nature of local air quality problems? Although alternative fuels clearly yield NO_x reductions compared with diesel, they do not offer benefits in terms of lower CO or significantly lower PM. Because the primary effect of NO_x on air quality is its contribution to ozone formation, NO_x reductions have the most meaningful benefit in ozone nonattainment areas. In areas that are in attainment of ozone standards, but nonattainment for CO, the benefits of alternative fuels are not as great. Is the community willing to bear additional costs to convert to alternative fuels? Do local opinion leaders clearly understand both the costs and the benefits? What funding sources are available? Would implementation costs adversely affect service? The planning process for converting to alternative fuels should begin with a comprehensive study of the issues involved. It may be desirable to have an outside firm conduct the study, as the firm will (ideally) be disinterested, objective, and well informed.

The planning study should address a number of relevant issues:

- **Evaluating the air-quality benefits of alternative fuels in the context of the local air quality.**
- **Identifying sources of supply for the fuels under consideration.** How reliable are they? How distant? How much competition exists? Is the available fuel quality acceptably and uniformly high? (For example, does the gas utility employ wintertime peakshaving with LPG?) In certain areas, a particular fuel will be largely available from local sources (such as CNG, LNG, and LPG in the Gulf Coast area, and ethanol in the Midwest). A community may wish to support local industries through the transit agency's choice of fuel.
- **Determining the extent to which facility modifications are needed.** Appropriately qualified professional engineers should evaluate facility modifications that will be needed for alternative fuels and estimate the associated costs. Code provisions stipulate minimum setbacks for fueling stations from buildings and property lines. Is enough space available at the existing garage(s) to accommodate fueling facilities for the alternative fuel? Will land have to be acquired? Is suitably located real estate available for sale or long-term lease? Would local building and fire officials impose any unusual design requirements? For CNG, does the existing gas pipeline have sufficient capacity to meet the large additional demand? If not, how much line must be upgraded, and who will bear the cost? Will electrical service to the garage have to be upgraded for compressor motors? To what design standards was the existing maintenance facility built: Diesel vehicles? Gasoline vehicles? Are existing ventilating rates high enough, or will ventilation have to be upgraded? Are there particular hazards, such as ceiling construction tending to trap gas leaks or open-flame heaters? How extensively will the fire protection system have to be upgraded?

2. Carefully evaluate the technological risks associated with the fuel options. A number of risks exist for transit agencies that are considering conversion to alternative fuels or other advanced, unconventional bus-propulsion technologies. These include the following:

- **Unanticipated safety hazards;**
- **Market obsolescence caused by the principal vendors no longer offering the product; and**
- **Adopting a technology before it is fully developed.**

Unanticipated safety hazards. During the commercialization of CNG, safety hazards have arisen that were not anticipated. These include the frequent failure of PRDs because of the effects of compression heating and the recent instances of leakage and failure of the Type IV (lightweight, all-composite) cylinders. Often, when a new technology is introduced, some of its properties or operating characteristics that potentially affect safety are not fully understood. The transit agency contemplating the introduction of a new fuel or propulsion technology should evaluate the level of such uncertainty that exists with the technology and candidly assess the organization's tolerance of mishaps that may result from this uncertainty.

Market obsolescence. New technologies are usually pioneered by one or two companies that have a vision that the new technology offers compelling advantages over existing products. If their new product is not commercially successful, small, entrepreneurial companies will likely stop offering warranty and technical support to existing owners of the product. For example, a company marketed a lightweight fiberglass-reinforced aluminum CNG tank in the early to mid-1990s. The company then left the market and sold the rights to the tank design to another company. This company offers support, such as repairs of damaged tanks, at much higher prices. As another example, a manufacturer of onboard LNG tanks, has since left this market, leaving the owners of the tanks virtually without product support. Such a prospect is possible for customers of battery-electric buses that are currently being sold by small entrepreneurial companies. Transit agencies contemplating purchasing innovative vehicles or components from such companies should do so with the understanding and acceptance of these risks.

Adopting a technology before it is fully developed. Modern diesel engine and drivetrain component designs are the culmination of decades of service experience. When properly integrated into a vehicle, they are remarkably reli-

TABLE 41 Summary of capital costs for transit bus fuel options

Fuel	Capital Cost Element		
	Vehicle Replacement	Fueling Facilities[a]	Maintenance Garage Modifications
Diesel	Lowest of any of the alternatives. \$250,000 ea., low floor or lift equipped, w/ air conditioning, HHD engine, electronic fare box & destination sign.	Costs are moderate and generally predictable. However, failing to contain leaks from underground storage tanks can lead to high remediation costs.	None. Existing garages are designed for diesel buses.
CNG	Most expensive except for hydrogen fuel cell. \$320,000 each, w/400 mi range. Equipped as with diesel, except that fire suppression system is normally specified.	Approximately \$1.7M for 200 bus facility. Design for high mechanical loads, high pressure, plus need for drying & filtration makes cost high.	Methane detection, increased ventilation, classified (explosion proof) electrical service in selected locations, and fire protection control system upgrades. \$600,000 median cost.
LNG	Somewhat less expensive than CNG, due to lower fuel tank cost. \$305,000 each, with fire suppression system and methane leak detection system.	Approximately \$1.8M for 200 bus facility — similar to CNG. Materials and designs for storing pumping and metering cryogenic fuels are costly. Mechanical and pressure loads are much lower than with CNG.	Same as CNG.
LPG	\$290,000 each. Vehicle cost is similar to, or somewhat less than LNG. LPG tanks are not insulated, making them less expensive than LNG tanks. LPG buses should be equipped with fire suppression systems.	Approximately \$700k. Design standards are quite mature; costs are predictable. Tanks must be strong enough to support moderate (250 psi) pressures. Fuel is non-toxic liquid at room temperature; material requirements are moderate.	None if garage is designed for gasoline vehicles. If not, increased ventilation, classified electrical service in low areas, and fire protection control system upgrades will be needed. Modifications should be less costly than for CNG or LNG, since LPG fuel leaks remain near the floor. \$340,000 median cost.
Methanol	Somewhat higher than diesel (\$280,000), due to larger fuel tank, higher engine cost and need for corrosion resistant materials in the fuel system. Fire suppression system is normally specified.	Somewhat higher than with diesel: Approximately \$440k. Wetted materials must be selected carefully to resist corrosiveness of the fuel; vapor recovery system must be added. 2x storage tank volume needed re diesel.	Similar to LPG.
Ethanol	Similar to methanol.	Similar to methanol.	Similar to LPG.
Hydrogen	Most expensive, likely to be \$500,000 ea. Would be used only in a fuel cell bus w/ CH_2 storage. Fire suppression system would be specified.	Designs are in conceptual stage. L-CH_2 is a possibility, as is curb-side reforming from methanol. Likely to be more expensive than with CNG.	Need to mitigate very buoyant, potentially explosive fuel leaks. Design standards and costs are not yet established.

[a]Facility costs are for a 200-bus garage.

able and durable. During the 1990s, transit bus fleets are being converted from two-stroke diesel engines with mechanical fuel systems to four-stroke engines with improved lubrication, metallurgy, and electronic controls. As a result, expected engine durability has increased from 150,000 to 250,000 mi. In comparison, emerging technologies, such as hybrid-electric, battery electric, and fuel-cell propulsion, and to a lesser degree gaseous fueling, lack the benefit of such experience. Either rigorous (and expensive) preproduction testing or several years in revenue service are needed to discover and rectify unexpected design weaknesses. Therefore, it is reasonable to assume that new propulsion technologies may suffer from comparatively poor reliability and durability for some time after their introduction.

The market problems of the methanol engine were due, in part, to an underestimation of the engineering effort needed to make the engine competitive with diesel or natural gas engines in reliability and durability. The engine was arguably

TABLE 42 Summary of operating costs for transit bus fuel options

Fuel	Operating Cost Element			
	Vehicle Operating	**Vehicle Maintenance**	**Fueling Facility O&M**	**Maintenance Garage O&M**
Diesel	Fueling cost = ($0.87/gal)/(4 mi/gal) = $.22/mi	Lowest except possibly for hydrogen fuel cell. New electronically-controlled four stroke diesel engines are significantly more durable and maintainable than earlier 2-stroke engines.	Low operating and maintenance costs. These include electric energy to pump fuel, annual tank pressure testing and operating permit renewal; and occasional servicing of dispensers and pumps.	Moderate HVAC energy costs: Ventilating rates must be high enough in repair bays to adequately dilute vehicle exhaust.
CNG	Fueling cost = ($0.326/thm gas + 0.08/ thm compression)/(2.14 mi/thm) = $.19/mi Bus is 35% less energy efficient than diesel bus.	Agencies report similar or moderately higher maintenance costs than with diesel buses. Greater engine complexity, design immaturity, and vehicle weight suggest that moderately higher maintenance costs will continue.	Highest, except possibly for hydrogen. High mechanical loads, vibration and fatigue wear potential exist with gas compressors. Gas dryers and filters need to be periodically serviced. Compression energy cost is significant.	Slightly higher maintenance costs exist re diesel for periodically testing and calibrating methane leak detectors.
LNG	Fueling cost = ($0.48/gal)/(1.83 mi/gal) = $.26/mi Bus is 30% less energy efficient than diesel bus.	Similar to CNG, except that rigorous inspection & maintenance programs in place for on-board CNG tanks at some agencies, could be avoided: LNG uses rugged moderate pressure tanks.	Lower than hydrogen or CNG, but higher than the other fuels. Mechanical and pressure loads are much lower than with CNG. Components are subjected to severe thermal cycling. Pumps, valve packings and gaskets may have to be frequently serviced or replaced.	Same as CNG.
LPG	Fueling cost = ($0.65/gal)/(1.92mi/gal) = $.34/mi Bus is 35% less energy efficient than diesel bus.	Similar to CNG.	Similar to diesel.	Similar to CNG, since fire protection system may also incorporate combustible gas detectors.
Methanol	Fueling cost = ($0.59/gal)/(1.54mi/gal) = $.38/mi Bus is 15% less energy efficient than diesel bus.	Transit agencies have experienced very high maintenance costs due to frequent premature engine failures involving injectors, liners and bearings. Operating life between rebuilds is often 1/2 to 1/3 of diesel baseline.	With properly designed facility, operating and maintenance costs should be similar to diesel facilities. Improper material selection can lead to elevated costs for replacing hoses, product filters and gaskets and seals.	Similar to LPG.
Ethanol	Fueling cost = ($1.08/gal)/(2.06 mi/gal) = $.52/mi Bus is 15% less energy efficient than diesel bus.	Similar to methanol.	Similar to methanol.	Similar to LPG.
Hydrogen	Not yet established; several fuel supply scenarios are possible.	Could yield lowest power train maintenance cost of any propulsion mode, due to extreme mechanical simplicity of the PEM fuel cell engine.	Fuel-island reformer designs are in conceptual stage, so no actual data exist. High system complexity and CNG-equivalent storage pressure suggest that operating and maintenance costs will be higher than with CNG.	No data exist, but likely to be higher than for CNG.

introduced prematurely, resulting in problems with reliability and durability in service.

CNG and LNG motor bus technology has benefited from a lengthy development effort and a high level of commitment by several engine manufacturers, gas utilities, research organizations, and other equipment vendors. Transit agencies may now evaluate and select CNG and LNG vehicles with reasonable confidence that the equipment involved is proven, serviceable, and durable. Technologies such as hybrid-electric propulsion and fuel cells are now in the advanced prototype stage of development and show great promise. The developers of these technologies usually say that they will ultimately offer better durability and maintainability than diesel or CNG motor buses, along with lower overall life-cycle costs. However, it would be premature for transit agencies to begin ordering hybrid-electric or fuel-cell buses now on the *assumption* that these goals will be realized. Before adopting a new fuel or propulsion technology for large-scale revenue operations, transit agencies should carefully evaluate its development status, assess how much further effort is needed to fully develop the technology, and evaluate the commitment and resources of the product's developers.

In most cases, it is advisable to demonstrate a candidate technology in several vehicles for at least a year before making a greater commitment. This enables the performance of the technology to be measured and evaluated in the agency's own operation over a long enough period that trends in fuel consumption, maintenance requirements, and durability can be established with some degree of certainty.

3. Conduct a thorough cost analysis of the candidate fuels or technologies. In the past, transit agencies have tended to focus on the operating cost impacts of alternative fuels and propulsion technologies and gave less attention to capital cost impacts. This has followed from the availability of outside funding for capital acquisitions. However, moving to an alternative fuel involves costly investments in fueling facilities and maintenance garage modifications that are long-lived. Alternative-fuel vehicles may entail a substantial replacement cost premium that may never go away. Capital subsidies from outside sources may decrease in the future or even become completely unavailable. For example, with the deregulation of the gas utility industry in many states, utility companies are no longer able to "rate base" or pass onto their customers the costs associated with subsidizing compressor station construction projects. As a result, gas utility cost sharing for compressor stations, which used to be reasonably available to transit agencies, is becoming much less available.

An evaluation of fuel or vehicle technology options should include a full life-cycle cost analysis of each option being considered over a period of at least 12 years. This should also include annualized budgets needed to meet anticipated capital expenditures as well as likely operating costs. The cost model developed for this study, *FuelCost 1.0,* provides a good starting point for this process. The relative capital and operating costs of the fuel and propulsion technology options considered in this study are summarized in Tables 41 and 42, respectively.

Lawn & Garden Equipment Rebate & Exchange Program

Sunday, April 27 - 10am-2pm

Trade in your old gas-powered lawn mower for a reel push mower and receive a $50 rebate check. Trade in your gas-powered trimmer or leaf blower and replace it with an electric model and receive a $25 rebate check. Trade in your old gas can and receive a FREE no-spill gas can.

Gas-powered lawn and garden equipment, along with other non-road engines, produce approximately 20% of the compounds which lead to smog each summer day. Let the Department of Environmental Protection help you trade in your polluting gas cans and equipment for cleaner alternatives and for cleaner air!

All mowers, trimmers and leaf blowers must be in working condition and must be scrapped at the April 27 Household Hazardous Waste Collection at the Upcounty Regional Service Center, Germantown. Participants will receive a copy of the official Reservation & Redemption form when they turn in their old equipment on April 27. To receive a rebate, submit the completed form with the UPC code and receipt from the purchase of your new equipment. A rebate will be mailed to you. Limited quantities of gas can and rebate checks are available*. Call and reserve yours today!

Call 240.777.7770
for reservations or more details.

*285 gas cans, 40 mower rebates 35 each leaf blower and trimmer rebates; only one can or rebate per household.

Exchange program made possible through the cooperation of the Montgomery County Department of Public Works and Transportation, Division of Solid Waste Services.

Department of Environmental Protection
Montgomery County Maryland

Lawn & Garden Equipment Rebate & Exchange Program

Sunday, April 27 - 10am-2pm

Trade in your old gas-powered lawn mower for a reel push mower and receive a $50 rebate check. Trade in your gas-powered trimmer or leaf blower and replace it with an electric model and receive a $25 rebate check. Trade in your old gas can and receive a FREE no-spill gas can.

Gas-powered lawn and garden equipment, along with other non-road engines, produce approximately 20% of the compounds which lead to smog each summer day. Let the Department of Environmental Protection help you trade in your polluting gas cans and equipment for cleaner alternatives and for cleaner air!

All mowers, trimmers and leaf blowers must be in working condition and must be scrapped at the April 27 Household Hazardous Waste Collection at the Upcounty Regional Service Center, Germantown. Participants will receive a copy of the official Reservation & Redemption form when they turn in their old equipment on April 27. To receive a rebate, submit the completed form with the UPC code and receipt from the purchase of your new equipment. A rebate will be mailed to you. Limited quantities of gas can and rebate checks are available*. Call and reserve yours today!

Call 240.777.7770
for reservations or more details.

*285 gas cans, 40 mower rebates 35 each leaf blower and trimmer rebates; only one can or rebate per household.

Exchange program made possible through the cooperation of the Montgomery County Department of Public Works and Transportation, Division of Solid Waste Services.

Department of Environmental Protection
Montgomery County Maryland

Exhaust Emission Controls Available to Reduce Emissions
from
Nonroad Diesel Engines

April 2003

Manufacturers of Emission Controls Association
1660 L Street, NW • Suite 1100 • Washington, DC 20036 • tel: (202) 296-4797 • fax: (202) 331-1388
www.meca.org

Table of Contents

Table of Figures

Exhaust Emission Controls Available to Reduce Emissions from Nonroad Diesel Engines

Introduction

A wide variety of nonroad diesel engines are in-use today, ranging from agricultural tractors, to construction and mining equipment, to forklift trucks used for materials handling. The engines used to power these vehicles can be relatively small, in the range of <75 horsepower, or as large as >750 hp. The duty cycles of nonroad vehicles also vary considerably, with some applications being relatively steady state (e.g., agricultural tractors) and others being transient in nature (e.g., nonroad haulage trucks).

The use of exhaust emission control technology for nonroad diesel engines is not new. For well over twenty five years, nonroad diesel engines in vehicles in the construction, mining, and materials handling industries have been equipped with exhaust emission control technology – initially with diesel oxidation catalysts (DOCs) followed later by particulate filter systems (DPFs). Worldwide, over 250,000 nonroad vehicles and equipment have been equipped with exhaust emission control technology. The technology has provided important pollution reductions and has demonstrated excellent durability both as original equipment and as retrofit technology. Recently, selective catalytic reduction (SCR) for NOx emission control has also been used in select nonroad diesel engine applications including marine vessels and locomotives.

As states look for new ways to achieve the National Ambient Air Quality Standards (NAAQS) for both particulate matter (PM) and ozone, exhaust emission control of nonroad diesel engines is critical. Engine design improvements combined with exhaust emission control technology offer great potential for significantly reducing emissions from nonroad diesel engines. Generally, the technologies, such as DPFs and NOx adsorbers, and integration strategies being developed to meet the 2007 and 2010 heavy-duty onroad diesel engine standards can be applied to nonroad diesel engines and vehicles. Also, SCR, widely used on stationary engines, will be a NOx control option, as will exhaust gas recirculation (EGR) technology.

Smaller engines, typically less than 75 hp, present special challenges in that they will need on-highway type fueling systems to employ the same technologies being developed for highway vehicles. Specifically, the capability to modulate between lean and rich operation will be needed to employ NOx adsorber catalysts. Therefore, either the capability to have in-cylinder post fuel injection or supplemental in-exhaust fuel addition systems will need to be developed for these engines. Also, in order to employ SCR for NOx control, these engines will need to be equipped with appropriate electronic control units and urea injection systems. Employing PM filters on these engines will also require that the necessary technology be employed to ensure that filter regeneration is achieved. While these challenges exist, they can be addressed. For example, options already exist for filter regeneration for small engines as is discussed below. Furthermore, DOCs can be readily applied to these engines to significantly reduce emissions today.

Today's nonroad diesel engines are characterized by relatively high engine-out emissions. An important part of the emission control system approach will be to reduce engine-out emissions to enable exhaust emission control to be effectively employed and to make the truly clean nonroad engine a reality. A systems approach combining the best in engine and emission control technology is being successfully applied in other mobile source applications and can certainly be utilized in reducing emissions from nonroad diesel engines. As is the case with onroad diesel engine emission control, diesel fuel containing <15 ppm sulfur is absolutely essential to maximize the control and operating capabilities of exhaust emission control technologies.

As noted above, although challenges exist in reducing emissions from nonroad diesel engines, the technologies – both engine based and exhaust emission control technologies – exist today and continue to rapidly develop. These technologies in combination with low (<15 ppm) sulfur diesel fuel and appropriate system integration strategies can be used to significantly reduce emissions from nonroad diesel engines. It will be the transference of these technologies and the integration strategies being developed to enable onroad engines to meet the upcoming 2007 requirements to the nonroad sector that will enable nonroad diesel engines to operate clean.

This paper was prepared to summarize the experience with emission control technologies on nonroad diesel engines. The control capabilities, as well as the operating experience with the technologies in various applications, are highlighted. Also, the opportunities and challenges for the reduction of emissions from future nonroad diesel engines are reviewed.

Description of Diesel Exhaust Emission Control Technologies Options for Nonroad Diesel Engines

Several exhaust emission control technologies are and will be available to substantially reduce emissions from nonroad diesel engines. These include diesel particulate filters (DPFs), diesel oxidation catalysts (DOCs), lean NOx catalysts, NOx adsorbers, and selective catalytic reduction (SCR). Crankcase emissions can also be controlled from nonroad diesel engines.

Diesel Particulate Filters (DPFs)

As the name implies, diesel particulate filters remove particulate matter in diesel exhaust by filtering exhaust from the engine. They can be installed on nonroad vehicles and equipment or stationary diesel engines. Since a filter can fill up over time, engineers that design filter systems must provide a means of burning off or removing accumulated particulate matter. A convenient means of disposing of accumulated particulate matter is to burn or oxidize it on the filter when exhaust temperatures are adequate. By burning off trapped material, the filter is cleaned or "regenerated". Both exhaust gas temperature and diesel fuel sulfur level have to be taken into consideration.

In some nonroad applications, disposable filter systems have been used. A disposable filter is sized to collect particulate for a working shift or some other predetermined period of time. After a prescribed amount of time or when backpressure limits are approached, the filter is removed and cleaned or discarded. To ensure proper operation, filter systems are designed for the particular vehicle and vehicle application.

A number of filter materials have been used in diesel particulate filters, including: ceramic and silicon carbide materials, fiber wound cartridges, knitted silica fiber coils, ceramic foam, wire mesh, sintered metal substrates, and temperature resistant paper in the case of disposable filters. Collection efficiencies of these filters range from 50 to over 90 percent. Filter materials capture particulate matter by interception, impaction and diffusion. Filter efficiency has rarely been a problem with the filter materials listed above, but work has continued to: 1) optimize filter efficiency and minimize backpressure, 2) improve the radial flow of oxidation in the filter during regeneration, and 3) improve the mechanical strength of filter designs.

Many techniques can be used to regenerate a diesel particulate filter. Some of these techniques are used together in the same filter system to achieve efficient regeneration. Both on- and off-board regeneration systems exist. The major regeneration techniques are listed below.

- *Catalyst-based regeneration using a catalyst applied to the surfaces of the filter.* A base or precious metal coating applied to the surface of the filter reduces the ignition temperature necessary to oxidize accumulated particulate matter.

- *Catalyst-based regeneration using an upstream oxidation catalyst.* In this technique, an oxidation catalyst is placed upstream of the filter to facilitate oxidation of nitric oxide (NO) to nitrogen dioxide (NO_2). The nitrogen dioxide adsorbs on the collected particulate substantially reducing the temperature required to regenerate the filter.

- *Fuel-borne catalysts.* Fuel-borne catalysts reduce the temperature required for ignition of trapped particulate matter.

- *Air-intake throttling.* Throttling the air intake to one or more of the engine cylinders can increase the exhaust temperature and facilitate filter regeneration.

- *Post top-dead-center (TDC) fuel injection.* Injecting small amounts of fuel in the cylinders of a diesel engine after pistons have reached TDC introduces a small amount of unburned fuel in the engine's exhaust gases. This unburned fuel can then be oxidized in the particulate filter to combust accumulated particulate matter.

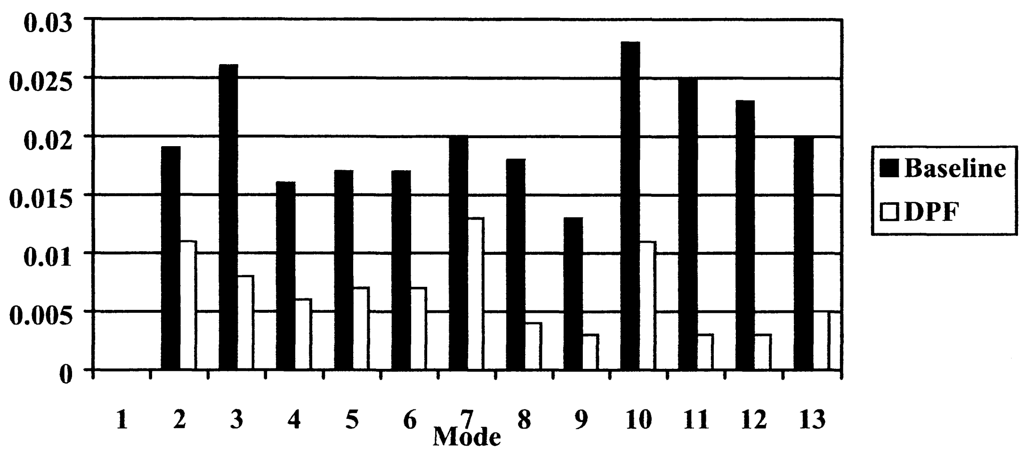
- *On-board fuel burners or electrical heaters.* Fuel burners or electrical heaters upstream of the filter can provide sufficient exhaust temperatures to ignite accumulated particulate matter and regenerate the filter.

- *Off-board electrical heaters.* Off-board regeneration stations combust trapped particulate matter by blowing hot air through the filter system.

Sulfur affects filter performance by inhibiting the performance of catalytic materials upstream of or on the filter. This phenomenon not only adversely affects the ability to reduce emissions, but also adversely impacts the capability of these filters to regenerate – there is a direct trade-off between sulfur levels in the fuel and the ability to achieve regeneration. Sulfur also competes with chemical reactions intended to reduce pollutant emissions and creates particulate matter through catalytic sulfate formation. The availability of very low, <15 ppm sulfur fuel will enable these filters to be designed for improved PM filter regeneration and emission control performance, as well as to minimize any increase in sulfate emissions. Indeed, diesel fuel containing <15 ppm sulfur is required to ensure maximum emission control performance on the broadest range of diesel nonroad engines possible.

Emissions control performance of DPFs is well established. While most emission testing has been performed on transient test cycles where PM reductions in excess of 90 percent have been demonstrated time and time again, steady state test data also exists as shown in Figure 1 (Reference 1). This testing was performed using fuel containing 54 ppm sulfur.

Figure 1. 13-Mode Steady-State DPF Control Performance (g/bhp-hr)



As can been seen the control performance of catalyst-based DPFs is affected adversely by even 54 ppm sulfur in the fuel for some operating modes due to the formation of H_2SO_4. The use of lower (e.g., <15 ppm) sulfur fuel is essential to achieving the greater PM control efficiencies that will be needed to achieve truly low emission levels in nonroad engine applications. In fact, in a joint government industry research program aimed to investigate the effects of diesel fuel sulfur content on emissions from heavy-duty diesel engines, two different diesel particulate filters were evaluated for their PM emission control performance with fuels containing different fuel sulfur levels on the steady-state 13 mode OICA test cycle (Reference 2). When testing with 3-ppm sulfur fuel both filter systems achieved a 95 percent PM emission reduction.

Another advantage of the use of DPFs on diesel-powered nonroad engines is their ability to dramatically reduce toxic HC emissions. The capability of two separate catalyst-based DPF systems to reduce 18 distinct polyaromatic hydrocarbons (PAHs) has also been evaluated (Reference 1). On average, the PAHs were reduced by 89 and 84 percent, respectively. The testing was performed over the U.S. Federal Test Procedure (FTP). Although the FTP is a transient test cycle used for motor vehicles, the results would be similar, or better, on a steady state test cycle because of the relatively low load associated with the FTP and corresponding exhaust gas temperatures (the catalyst function of the filter performs better at elevated temperatures). Also, DPFs control in excess of 99 percent of the carbon-based ultrafine particles (SAE Paper 2000-01-0473).

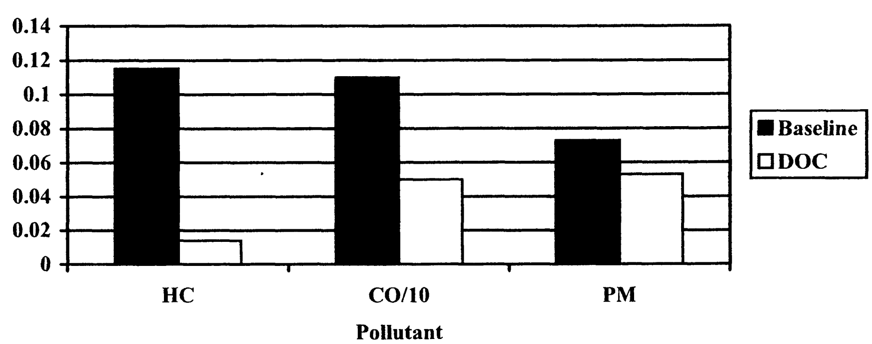
As noted, DPFs are commercially available today. Over 70,000 onroad, heavy-duty vehicles and 400,000 diesel passenger cars have been equipped with the technology. Nevertheless, development work continues to improve the technology focusing on such areas as improving filter design, structural integrity, materials, geometries, as well as improving filter regeneration performance (SAE Papers 2002-01-0322, 2002-01-0325, 2002-01-0323, and 2003-01-0378).

Diesel Oxidation Catalysts (DOCs)

Diesel oxidation catalyst is a technology that is available today and could be readily applied to virtually the entire range of nonroad engine applications. Over 250,000 nonroad vehicles and equipment including mining vehicles, skid steer loaders, forklift trucks, construction vehicles and stationary engines, as well as, over 35,000,000 diesel passenger cars have been equipped with the technology.

The principle behind a diesel oxidation catalyst for the control of emissions from a diesel engine is that the catalyst causes chemical reactions without being changed or consumed. An emission control catalyst system consists of a steel housing, whose size is dependent on the size of the engine for which it is being used, that contains a metal or ceramic structure, which acts as a catalyst support or substrate. There are no moving parts, just acres of interior surfaces on the substrate coated with either base or precious catalytic metals such as platinum group metals. Catalysts transform pollutants into harmless gases by causing chemical reactions in the exhaust stream. Diesel oxidation catalysts serve to reduce PM, CO, HC, and toxic HC emissions. PM emissions are reduced by the chemical transformation of the soluble organic fraction (SOF) to carbon dioxide and water. DOCs can reduce total PM emissions by up to 50 percent depending on the amount of SOF in the PM and the amount of sulfur in the fuel. Figure 2 highlights the emissions control performance of a DOC as measured over the heavy-duty engine FTP with fuel containing 368-ppm sulfur (Reference 1). Even with the high sulfur content used, a 27 percent reduction in PM was achieved on the MY 1998 engine.

Figure 2. DOC Performance (g/bhp-hr)



Like catalyst-based DPFs, oxidation catalysts are effective in controlling toxic HC emissions. The control capabilities of two DOCs were evaluated for 18 distinct PAHs (Reference 1). Reductions in excess of 50 percent are readily achieved with reductions approaching 70 percent possible. Similar or better results can be expected on steady-state test cycles for the reasons mentioned above for catalyst-based DPFs.

Diesel oxidation catalysts are virtually maintenance-free. Periodic inspection to ensure that cell plugging is not occurring is advisable. Cell plugging, if it occurs at all, would be limited to those situations such as engine malfunction (e.g., a faulty injector or two) or where there is prolonged idle in cold ambient temperatures (e.g., multi-day idling in Alaska). On-board diagnostic techniques like backpressure monitoring can be used to alert the operator in these rare instances when plugging might occur and the catalysts can easily be removed, cleaned and reinstalled.

Like diesel particulate filters, diesel oxidation catalysts are also affected by sulfur. The sulfur content of diesel fuel is critical to applying catalyst technology. Catalysts used to oxidize the SOF of the particulate can also oxidize sulfur dioxide to form sulfates, which is counted as part of the particulate. This reaction is not only dependent on the level of sulfur in the fuel, but also the temperature of the exhaust gases. Catalyst formulations have been developed which selectively oxidize the SOF while minimizing oxidation of the sulfur dioxide. However, the lower the sulfur content in the fuel, the greater the opportunity to maximize the effectiveness of oxidation catalyst technology for both better total control of PM and greater control of toxic HCs. Lower sulfur fuel (500 ppm), which was introduced in 1993 throughout the U.S., has facilitated the application of catalyst technology to diesel-powered vehicles. Very low fuel sulfur (<15 ppm) would further enhance the control capabilities of DOCs.

NOx Adsorber Catalysts

NOx adsorber catalysts are currently being used commercially in light-duty gasoline direct injection (GDI) engines. This technology is also undergoing extensive research and development in anticipation of the U.S. 2007 on-road heavy-duty diesel engine regulations and to help significantly reduce NOx emissions from light-duty diesel vehicles. The progress in developing and optimizing this technology has been extremely impressive.

NOx adsorbers act to store NOx emissions during lean engine operation and release the stored NOx by periodically creating a rich exhaust environment by either engine operation or the injection of a reductant in the exhaust stream. When released the NOx is converted to N_2 by a three-way catalytic reaction. In the laboratory, NOx adsorbers have demonstrated the ability to control up to 90 percent or more of the engine out NOx emissions over a broad temperature range as shown in Figure 3. Also, excellent progress has been made in improving the thermal durability of NOx adsorbers as illustrated in Figure 4. A Toyota vehicle equipped with a combined NOx adsorber/PM filter system came close to meeting the EPA Tier 2, bin 5 emission standards with a low-mileage emission system. A 60-vehicle fleet equipped with Toyota's combined NOx adsorber/PM filter technology is now undergoing road testing in Europe. A HDE NOx/PM system tested at EPA's laboratory achieved emission levels below the 2007 HDE emission standards of 0.2g/bhp-hr NOx and 0.01 g/bhp-hr PM using low mileage emission components.

The current focus of NOx adsorber technology development and optimization is on: 1) expanding the operating temperature window in which the technology will perform, 2) improving the thermal durability of the technology, 3) improving the desulfurization methods and performance, and 4) improving system packaging and integration. While NOx adsorber catalysts are not currently available for nonroad diesel engines, NOx adsorber and the associated engine technologies will be available for use on nonroad diesel engines in the future. The incorporation of on-highway type fueling systems will allow for the use of NOx adsorber technology on the smaller engines as well.

Low sulfur diesel fuel – <15 ppm sulfur – is absolutely essential to commercializing NOx adsorber systems that can function effectively for both onroad and nonroad diesel engine applications. At higher sulfur levels, a NOx adsorber quickly becomes ineffective as the sulfur attaches to the sites meant to "trap" the NOx. The sulfur remains attached to these sites until high temperature, rich conditions, which are not characteristic to normal diesel engine operation, are met. Also, while a sulfur regeneration mode or desulfurization cycle will need to be employed in any case, the frequency of desulfurization must be kept to a minimum to avoid substantial fuel economy penalties and perhaps a degradation of the NOx adsorber performance that, in turn, will require an even more frequent desulfurization. As the sulfur level increases, the frequency, as well as the severity, of reservations needed increases.

Figure 3. Improvements in NOx Control Efficiency

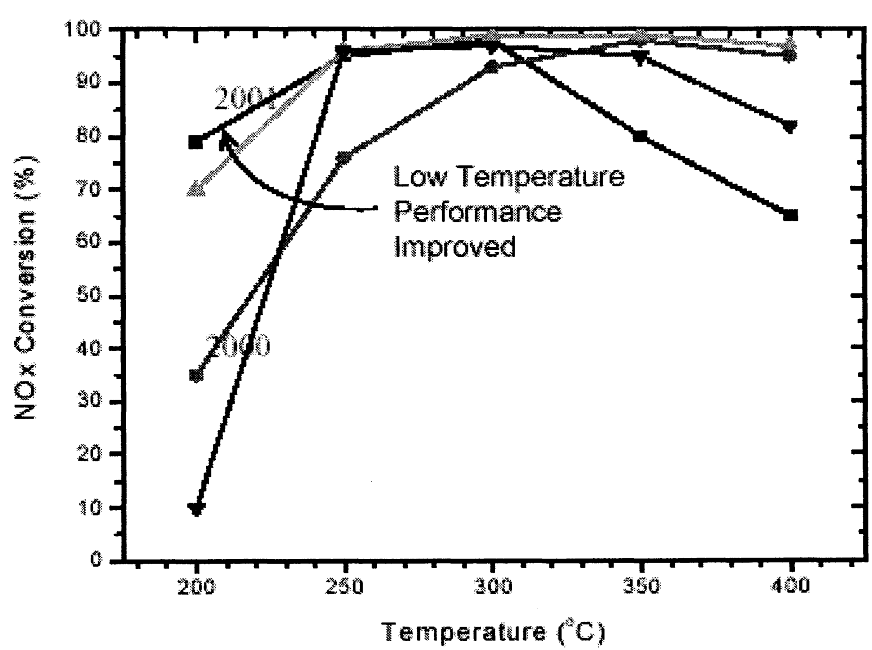
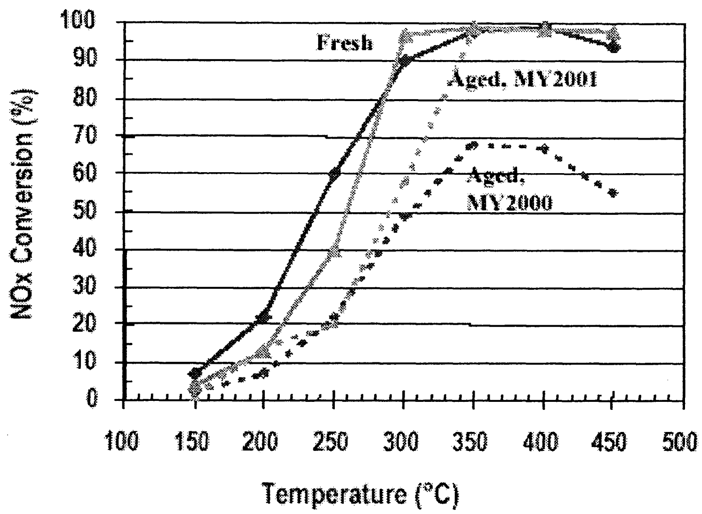


Figure 4. Improvements in Thermal Durability



Selective Catalytic Reduction

SCR has been used to control NOx emissions from stationary sources for over 15 years. More recently, it has been applied to select mobile sources including trucks, marine vessels, and locomotives. Applying SCR to diesel-powered engines provides simultaneous reductions of NOx, PM, and HC emissions.

Like an oxidation catalyst, the catalyst in an SCR system allows chemical reactions to take place that would not take place during normal engine operation. Again, like an oxidation catalyst, the SCR catalyst enables chemical reactions without being consumed itself. Unlike an oxidation catalyst, however, a SCR system needs a chemical reagent, a reductant, to convert nitrogen oxides to molecular nitrogen and oxygen in the exhaust stream. The reductant is typically urea or ammonia (NH_3). The reductant is added at a rate calculated from an algorithm that estimates the amount of NOx present in the exhaust stream. The algorithm relates NOx emissions to engine operating conditions, for example engine revolutions per minute (rpm) and load. As exhaust gases and reductant pass over the SCR catalyst, chemical reactions occur that reduce NOx emissions 65 to in excess of 90 percent and, where an oxidation function is included, reduce HC emissions from 30 to 90 percent and PM emissions from 15 to 50 percent. In addition, toxic HC emissions reductions can be achieved if an oxidation component is incorporated into the catalyst. In these instances, reductions similar to a DOC will be achieved. Like all catalyst-based emission control technologies, SCR performance is enhanced by the use of low sulfur fuel.

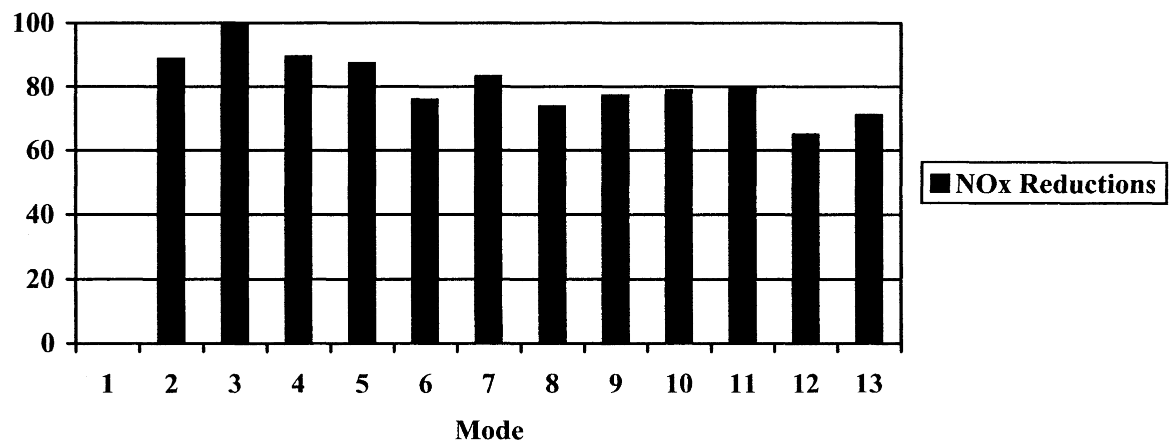
Both precious metal and base metal catalysts have been used in SCR systems. Base metal catalysts, typically vanadium and titanium, are used for exhaust gas temperatures between 450°F and 800°F. For higher temperatures (675°F to 1100°F), zeolite catalysts may be used. Precious metal SCR catalysts are useful for low temperatures (350°F to 550°F). In order to apply

SCR technology over the full range of nonroad engine applications and accompanying engine operating temperature windows, both types of catalysts likely will be utilized. SCR catalysts will benefit from the use of low sulfur fuel in terms of improved performance and minimizing sulfate formation when precious metals are used.

The control capabilities of SCR have also been evaluated (Reference 1). The NOx control performance is shown in Figure 5. As can be seen, NOx reductions ranged from approximately 65 percent in mode 12 to almost 100 percent in mode 3. Overall, a NOx reduction in excess of 80 percent was achieved.

Commercial application of SCR in the nonroad sector to date has been primarily on large marine and locomotive engines where the reductant can readily be stored onboard. The captive nature of many applications for nonroad diesel equipment makes more widespread use of this technology feasible in that the infrastructure requirements to ensure reductant availability can be more easily addressed than in the on-road highway sector.

Figure 5. 13-Mode SCR NOx Control Performance (% reduction)



Lean NOx Catalysts

Lean NOx catalyst systems have also been used on diesel engines. Some lean NOx catalysts rely on the injection of a small amount of diesel fuel or other reductant into the exhaust. The fuel or other hydrocarbon reductant serves as a reducing agent for the catalytic conversion of NOx to N_2. Other systems operate passively at reduced NOx conversion rates. The catalyst substrate is a porous material often made of zeolite. The substrate provides microscopic sites that are fuel/hydrocarbon rich where reduction reactions can take place. Without the added fuel and catalyst, reduction reactions that convert NOx to N_2 would not take place because of excess oxygen present in the exhaust. A hydrocarbon/NOx ratio of up to 6/1 is needed to achieve good NOx reductions. Since the fuel used to reduce NOx does not produce mechanical energy, lean NOx catalysts typically operate with a fuel penalty of about 3 percent. Currently, peak NOx conversion efficiencies typically are around 10 to 20 percent.

Two types of lean NOx catalyst formulations have emerged: a low temperature catalyst based on platinum and a high temperature catalyst utilizing base metals, usually copper. Each catalyst is capable of controlling NOx over a narrow temperature range. Combining high and low temperature lean NOx catalyst systems broadens the temperature range over which they convert NOx making them more suitable for practical applications.

Like all catalyst-based emission control technologies, the use of low sulfur diesel fuel enhances the performance of lean NOx catalysts. It also ensures that sulfate production is minimized allowing for maximum PM emissions control.

Crankcase Emission Control

Today, in most turbocharged diesel engines, the crankcase breather is vented to the atmosphere often using a downward directed draft tube to prevent fouling of the turbocharger and the resultant maintenance. While a rudimentary filter is often installed on the crankcase breather (the vent for the oil reservoir), a substantial amount of particulate matter is released to the atmosphere. For diesel engines used in motor vehicle applications, emissions through the breather may exceed 0.7 g/bhp-hr during idle conditions on recent model year engines.

One solution to this emissions problem is the use of a multi-stage filter designed to collect, coalesce, and return the emitted lube oil to the engine's sump. Filtered gases are returned to the intake system, balancing the differential pressures involved. Typical systems consist of a filter housing, a pressure regulator, a pressure relief valve and an oil check valve. These systems have the capability to eliminate crankcase emissions.

Factors to Be Considered When Applying Exhaust Emission Control Technology to Nonroad Engines

When equipping a nonroad vehicle with an exhaust emission control system, several items must be considered. These include:

- pollutant being controlled,
- exhaust gas temperatures and backpressure, and
- vehicle integration.

Pollutant Being Controlled

Exhaust emission control on nonroad vehicles was first used in the 1960s to address occupational health concerns and odor in closed working environments like underground mines and warehouses where diesel-powered and propane-powered equipment can be found. For occupational health reasons, the control technologies initially used targeted CO and HC. However, as diesel particulate emissions became recognized as a threat to workers' health, diesel particulate filters, which not only provided for control of CO and HC but also PM emissions, were developed and applied. Also, the ability of DOCs to reduce PM emissions was recognized. Today, technologies exist and are emerging to control CO, HC, PM, and NOx emissions from nonroad diesel vehicles. The application of a number of these control technologies will benefit from the extensive development and commercial experience in both new on-road vehicle and engines and with diesel engine retrofit.

Exhaust Gas Temperatures and Backpressure

An exhaust emission control system's performance is often dependent on exhaust gas temperature. Catalyst performance is mainly a function of temperature. The exhaust gases must be of sufficient temperature for catalyst light-off. The design of the system must take this into account. For example, a diesel particulate filter system which does not use an external heat source to initiate regeneration – a catalyst-based or "passive" DPF – will require exhaust gas temperatures high enough for this process to take place (usually around 300 deg C). The system's design should also minimize exhaust backpressure to eliminate or minimize any potential fuel economy penalties.

Diesel Fuel Properties

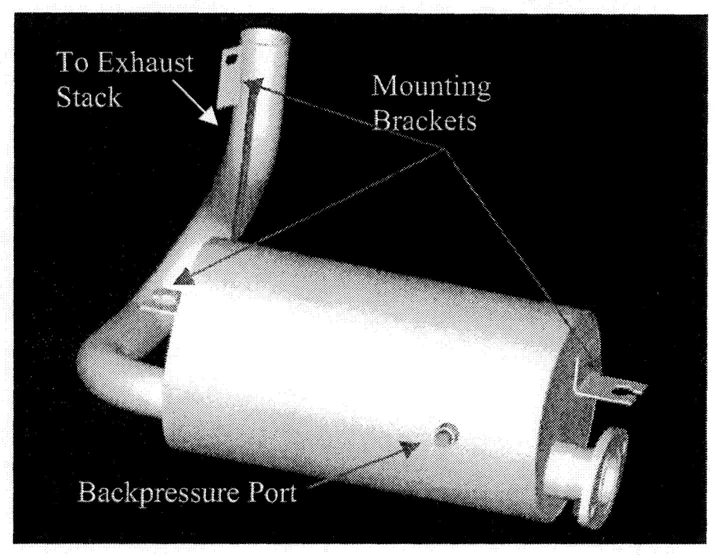
Low sulfur (<15 ppm) diesel fuel needs to be available to ensure that catalyst-based exhaust emission control technologies can be used most effectively. The low sulfur content will ensure that maximum performance and durability are achieved. It also ensures that sulfation does not occur and maximum PM emission reductions are achieved. Also importantly, it ensures that regeneration of catalyst-based DPF systems occurs at the lowest possible temperature ensuring their reliability on a broad range of nonroad diesel vehicles. DOCs have successfully been used to reduce emissions from urban buses with fuel containing up to 500 ppm sulfur under EPA's mandatory rebuild retrofit program where PM emissions reductions in excess 25 percent are being achieved.

In order to apply NOx adsorber technology to nonroad diesel engines, it is imperative that low (<15 ppm) sulfur diesel fuel be available.

Vehicle Integration

Vehicle integration is important from three points of view: 1) to ensure the system is installed at the appropriate place in the exhaust system to provide optimum performance (as discussed above), 2) to ensure the system fits in the available space, and 3) safety. Integrating controls has been successfully accomplished over the years on a variety of nonroad vehicles and equipment. Currently, many of the systems for nonroad vehicles are integrated into a muffler, which is used to replace the standard muffler as illustrated in Figure 6 for a forklift truck.

Figure 6. Schematic of a Muffler Incorporating a DOC for a Forklift Truck

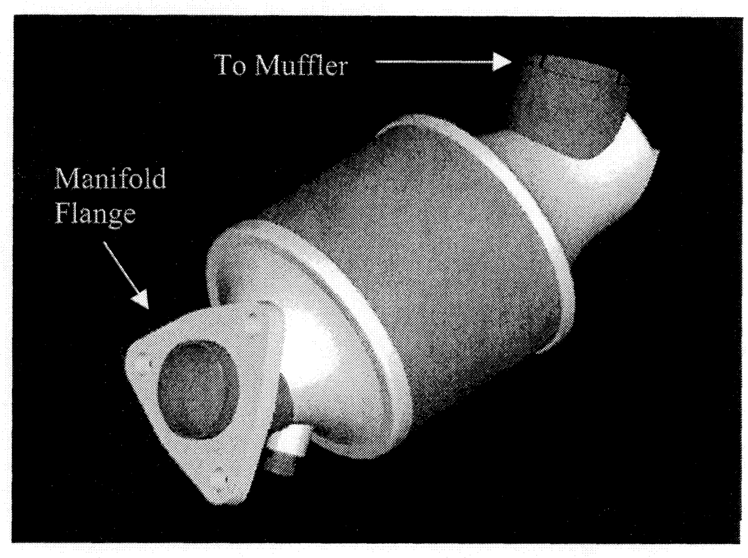


Although sometimes a challenge for existing vehicles where exhaust emission control technology has been retrofitted to the vehicle, past experience has shown that control equipment integration on nonroad vehicles and equipment is not as difficult as many believe. DOCs have also been designed to fit close-coupled to the manifold in the existing engine compartment. Figure 7 is a schematic of one such design also for a forklift truck. The ability to close-couple the technology to the engine manifold can be used to maximize the performance of exhaust emission control technology by taking advantage of the elevated temperatures in this position.

Even on very small engines, exhaust emission controls can be successfully integrated. Two examples of this having been accomplished in the past are 1) the successful design and installation of over 15 million catalysts worldwide on small motorcycles and mopeds, and 2) the installation of catalyst technology on lawn and garden equipment such as chainsaws, trimmers, and lawn mowers in the U.S. and Europe. The same type of innovations in design and packaging can be applied to even the smallest-sized nonroad diesel engines.

DPFs have also been successfully integrated onto nonroad vehicles. Figure 8 shows a small forklift truck equipped with a diesel particulate filter system that is regenerated using off-vehicle power. The system includes not only the filter, but also a heater element and appropriate wiring to allow the vehicle to be plugged into an electrical regeneration station. Operator visibility was not impaired. Similarly, DPFs have been installed on large vehicles. Figure 9 depicts a locomotive grader equipped with a catalyst-based DPF that regenerates passively. The engine size required that four filters in series be used. As can be seen, the installation accomplished while successfully insuring operator visibility with the filter installed on top of the existing muffler and inline with the existing exhaust stack.

Figure 7. A Close-Coupled DOC for a Forklift Truck

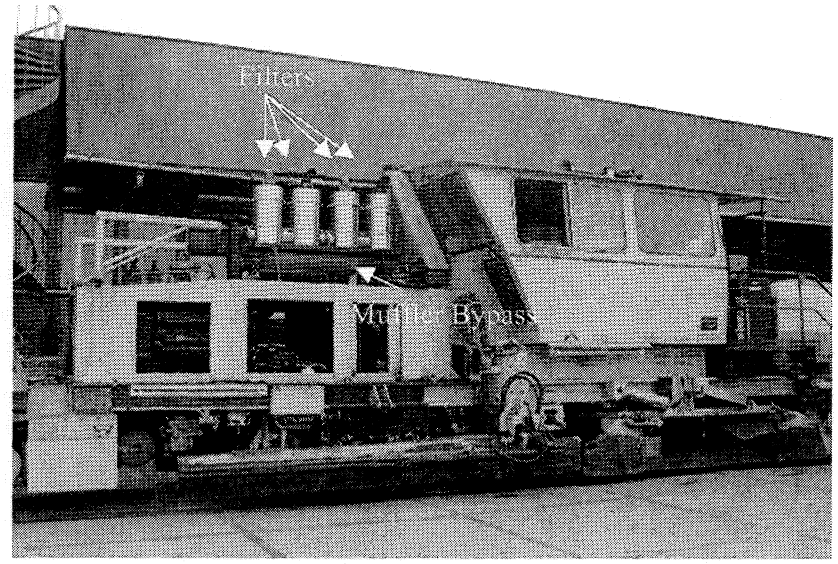


Also, exhaust emission control technology can be designed and integrated on to vehicles to address special operating concerns and environments. For example, where equipment is used in explosive operating environments, such as underground coal mines, emission control technology has been designed to meet special surface temperature requirements. Also, exhaust emission control technologies can and have been installed on vehicles so as not to impair operator visibility.

The examples highlighted above illustrate the feasibility of integrating retrofit exhaust emission control technology onto nonroad vehicles. Integration at the time of manufacture will afford considerable additional opportunities to further simplify and optimize the installation of emission control technology.

Figure 8. A DPF System on a Small Forklift Truck

Figure 9. A Locomotive Grader Equipped with a DPF



An important aspect of vehicle integration is to ensure that the vibration associated with the operation of nonroad vehicles can be withstood to ensure that the systems are indeed durable. A testament to the fact that this can be achieved is the fact that the systems have been used in underground mining applications for years with DOCs having been in service for the life of the vehicle and DPFs having been installed on equipment that has operated for over 15,000 hours in rugged work environments and still provided effective emission reduction performance. SCR systems have also proven durable in nonroad applications.

In a joint government/industry program (Reference 3), an underground field evaluation of diesel particulate filters was undertaken both to determine the effectiveness of DPFs to reduce underground miner workers' exposure to diesel emissions and to learn how to ensure that the technology could be used effectively in a rugged underground environment. Part of the demonstration was to evaluate durability. Two catalyst-based filters were operated in an underground mine for over 4,000 hours and returned to Environment Canada's emissions testing laboratory to determine the filters' performance. The testing was performed over an 8-mode steady state test cycle on a Detroit Diesel Series 50 engine. Their performance was then compared to a new unused filter provided by the same manufacturer. The two filters returned from the mine site averaged a PM emission of 0.01 g/bhp-hr – the same level of control achieved from the new filter. This result confirmed that the two filters having been installed in the mine had undergone very little – if any – deterioration.

The fact that exhaust emission control technologies have been used for many years in nonroad applications and proven to be durable attests to the fact the technologies can withstand the dust and moisture associated with many of the nonroad environments where the technologies have been used.

Experience with Exhaust Emission Control Technologies on Diesel-Powered Nonroad Vehicles and Equipment

Experience with exhaust emission control technologies on nonroad diesel engines and vehicles include diesel particulate filters, oxidation catalysts, and selective catalytic reduction.

Diesel Particulate Filters

Both "active" and "passive" DPFs have been used on diesel-powered nonroad vehicles in a wide variety of applications including:

- mining and tunneling,
- materials handling,
- construction.

Diesel particulate filters have been installed on nonroad equipment since 1986 including mining and construction vehicles, skid steer loaders, forklift trucks, large stationary engines, and others. Over 20,000 active and passive systems have been installed as either original equipment or as a retrofit worldwide. Some nonroad filter systems have been operated for over 15,000 hours or over 5 years and are still in use. Germany, Austria and Switzerland have established mandatory filter requirements for underground mining and tunneling equipment.

DPFs have been used on engines rated at several hundred horsepower, but also on smaller engines under 75 horsepower with tens of thousands systems having been installed on forklift trucks primarily in Europe since the early 1990s. In fact, filter systems are now being installed by the original equipment manufacturers. Many of the systems on the smaller engines are regenerated actively either offboard or onboard with electrical burners because of the low exhaust gas temperatures associated with the vehicle's operation.

Diesel Oxidation Catalysts

In the nonroad sector, oxidation catalysts have been installed on diesel vehicles 1986 for over 30 years with over 250,000 installations having been completed to date. A significant percentage of these units have been equipped to mining and materials handling vehicles, but construction equipment and other types of nonroad equipment have been equipped as well. The technology has been used on engines >75 hp and engines >750 hp. PM emissions, as well as CO and HC emission reductions, are targeted in these industries for occupational health concerns. Typically, these systems operate trouble free for several thousand operating hours and are normally replaced only when an engine undergoes a rebuild.

Selective Catalytic Reduction

SCR systems have also been installed on marine vessels and locomotives. Over 20 marine vessels have been equipped with SCR. The marine engines range from approximately 1250 hp to almost 10,000 hp and the installations have been in operation since the early to mid-1990s. Recently, the Swedish company SCA Graphic Paper announced it will equip its fleet of vessels with SCR technology to reduce NOx emissions by 90 percent.

Reducing Emissions from Nonroad Diesel Engines – Opportunities and Challenges

Applying exhaust emission control technology to future nonroad engines offers many very good opportunities, but also some challenges exist.

For all exhaust control technologies, reducing engine-out emissions will be an important step in controlling emissions from nonroad diesel vehicles and equipment. Many of the engine advances that either have been developed or are being developed for onroad highway vehicles should be readily transferable to similarly sized nonroad engines. Smaller diesel engines will need to employ improved fuel systems and achieve better oil consumption characteristics.

Diesel Particulate Filters

DPFs are proven to provide very high emissions reductions and to be durable. The technology as it exists today is applicable to many nonroad applications already. However, to make it applicable to all nonroad applications, active regeneration technology will be required. The types of regeneration technologies and strategies being developed for onroad vehicles will likely be used in the nonroad sector. Also, as noted above, other regeneration strategies have been successfully applied to nonroad engine applications. Other areas being investigated to facilitate the use of DPFs on nonroad diesel vehicles include improved catalyst formulations and size reduction.

Diesel Oxidation Catalysts

Like DPFs, DOCs are a proven technology. They can be applied to all nonroad diesel engine applications today to provide low cost emissions control. Although, currently, DOCs provide only modest PM emission reductions, improved substrate and catalyst formulations may provide higher reductions in the future. The availability of <15 ppm sulfur diesel fuel will further enhance the emission control performance of DOCs.

NOx Adsorbers

The fundamental concept behind NOx adsorber technology is applicable to all diesel engines. The technology also provides very high reductions in NOx emissions. In order for the technology to be used in nonroad applications, the engine controls required to modulate diesel engines between rich and lean operation and to allow for desulfurization will need to be applied to nonroad engines. Again, this technology will be transferable to nonroad diesel engines. Improved catalyst formulations and size reduction are being developed by manufacturers for onroad vehicle applications. These advances would also facilitate the use on NOx adsorbers in the nonroad sector.

Selective Catalytic Reduction

In order for SCR to find widespread use on nonroad vehicles, appropriate injection hardware and control algorithms need to be developed. These are engineering challenges that can be addressed.

Lean NOx Catalysts

Lean NOx catalysts can be used on all nonroad diesel engines for modest NOx emissions reductions.

Crankcase Emission Control

Technology exists to control crankcase emissions from all nonroad, turbocharged diesel engines.

Conclusion

A wide variety of vehicle compatible exhaust emission control systems have been used in nonroad vehicles for over thirty years. The technologies have evolved from targeting just CO and HC emissions to systems that also reduce PM and NOx emissions. Technologies such as DPFs and NOx adsorbers are currently being developed and optimized for onroad HDDEs and the experience gained will facilitate the application of these technologies to nonroad diesel engines. Special challenges exist in applying some technologies to the smaller nonroad diesel engines, but these are engineering challenges that with time can be addressed. The prospects for significantly reducing emissions from nonroad vehicles and equipment in the years ahead are excellent and exhaust emission controls can and will play an important role. Low (<15 ppm) sulfur diesel fuel will be required to ensure high performance, reliable, and durable operation of all catalyst-based exhaust emission control technologies.

References

1. MECA, "Demonstration of Advanced Emission Control Technologies Enabling Diesel-Powered Heavy-Duty Engines to Achieve Low Emission Levels," June 1999, www.meca.org.
2. DECSE Phase I Interim Data Report No. 4: Diesel Particulate Filters, Jan. 2000, www.ott.doe.gov/DECSE.
3. DEEP – Diesel Emissions Evaluation Program, www.deep.org.

NOTE: For copies of the SAE papers cited in this document, go to www.sae.org.

PLEASE POST

DEPARTMENT OF PUBLIC WORKS
AND TRANSPORTATION

Douglas M. Duncan
County Executive

Albert J. Genetti, Jr., P.E.
Director

May 20, 2003

To: All Ride On Employees

From: Mark A. Gibson, Chief of Operations
Division of Transit Services

Subject: Idling Buses

We must do everything we can to assure a cleaner and healthier environment in Montgomery County. Therefore, the following procedure will be adopted immediately.

All operators and coordinators are instructed that all county vehicles must be turned off upon arrival, when taking layover, lunch break and bathroom break. All employees must not start their vehicles in excess of (3) three minutes prior to departure time.

Employees must not leave vehicles unattended with engine running. Serious disciplinary action will be administered.

Guidelines for cutting off engines during any layover:

A. Residential Areas – Upon arrival at the end of the line operators will immediately turn off the engine and heating/cooling unit. Three (3) minutes prior to scheduled departure, operator(s) will re-start engine and heating/cooling units.

B. Non-Residential Areas – Cold weather
Upon arrival at the end of line, operator(s) may allow the engine to idle for 3 minutes and then turn off heating/cooling system and engine. Operator(s) may re-start the engine and heating/cooling system after each (5) five minute period and allow engine to run for (3) three minutes. This process will be repeated after each (5) five minute period or (3) three minutes to schedule departure time, whichever comes first.

C. Under no circumstances will operator idle engine in excess of (3) three consecutive minutes. The only exception is if Central Communications and /or a Maintenance (Fleet) Supervisor instructs you not to turn off your vehicle due to equipment malfunctions or you are instructed by the Police or Fire Department.

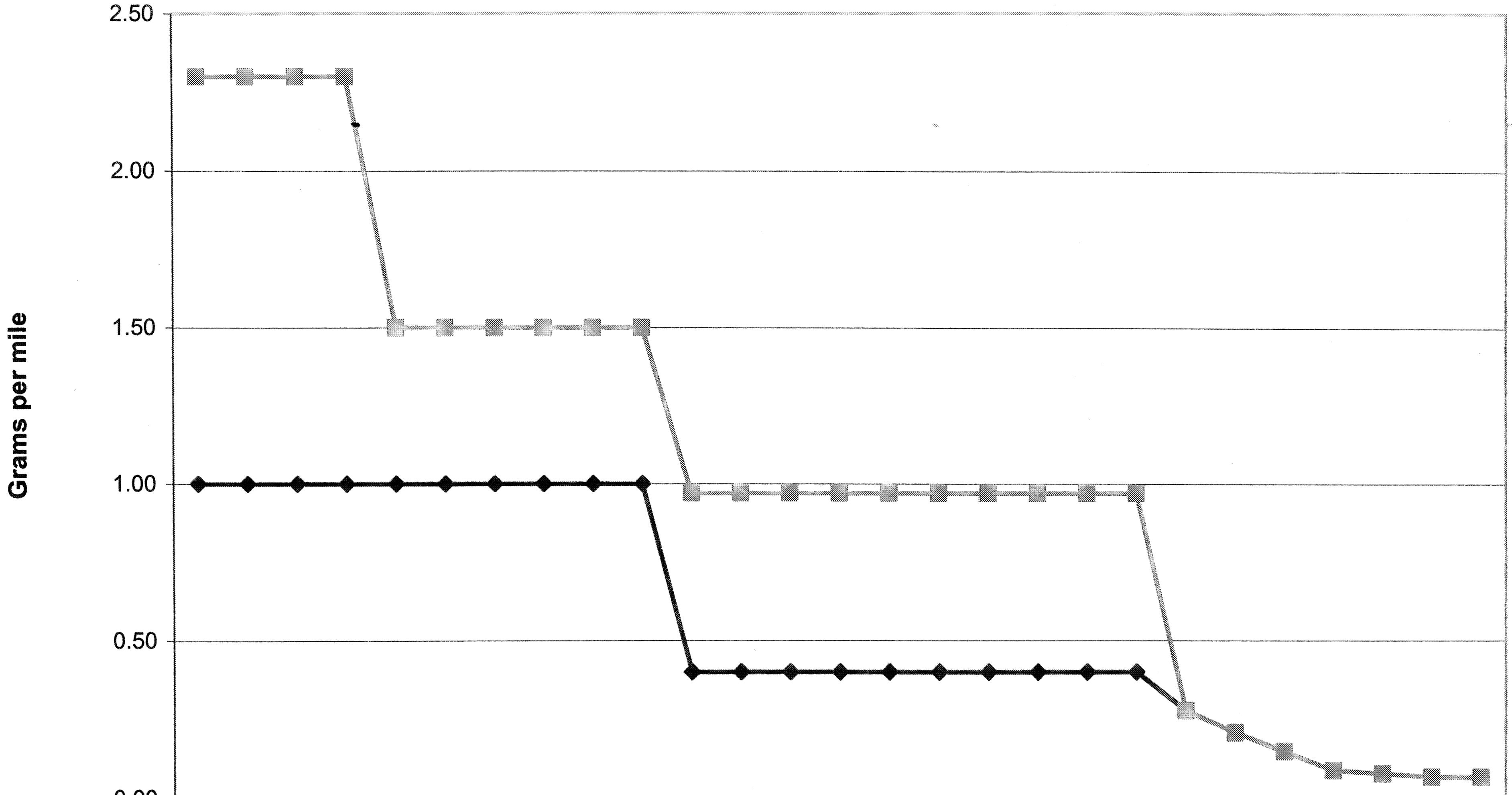
Thank you in advance for your help. We must do our part to improve the environment.

MAG/jmc

©M-122

Division of Transit Services
101 Monroe Street, 5th Floor • Rockville, Maryland 20850
240/777-5800, TDD 240/777-5869, FAX 240/777-5801 • www.dpwt.com • email: transit.dpwt@co.mo.md.us
Located one block west of the Rockville Metro Station

Passenger Car and Light Truck Emission Rates by Model Year
NITROGEN OXIDE (NOx)

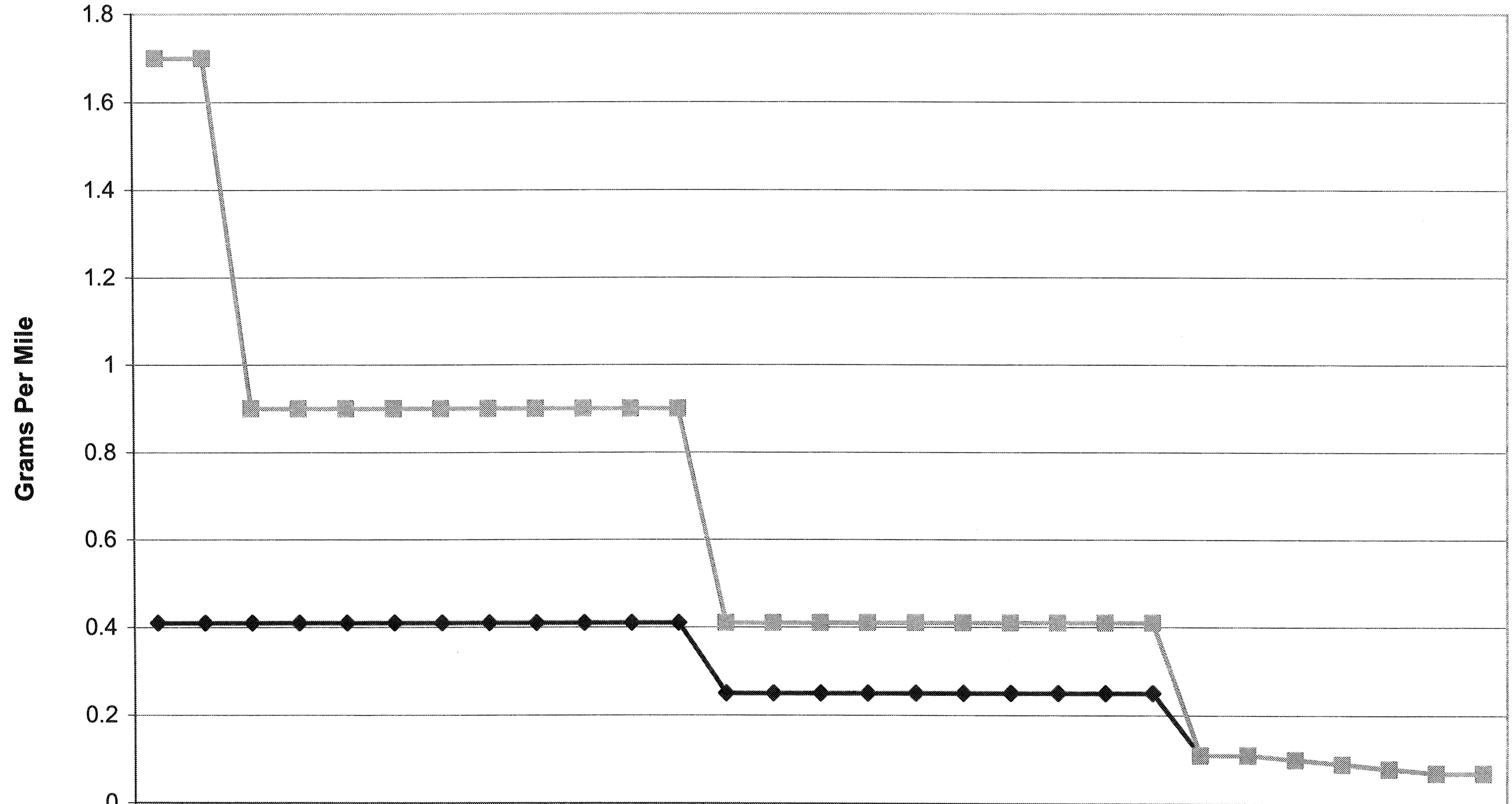


	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Pass Car	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.28	0.21	0.15	0.09	0.08	0.07	0.07
Lt Truck	2.30	2.30	2.30	2.30	1.50	1.50	1.50	1.50	1.50	1.50	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.28	0.21	0.15	0.09	0.08	0.07	0.07

Model Year

Source: Edwards and Kelcey Inc., OLO, 2003

Passenger Car and Light Truck Emission Rates by Model Year
NON-METHANE HYYDROCARBONS (NMHC or VOC)

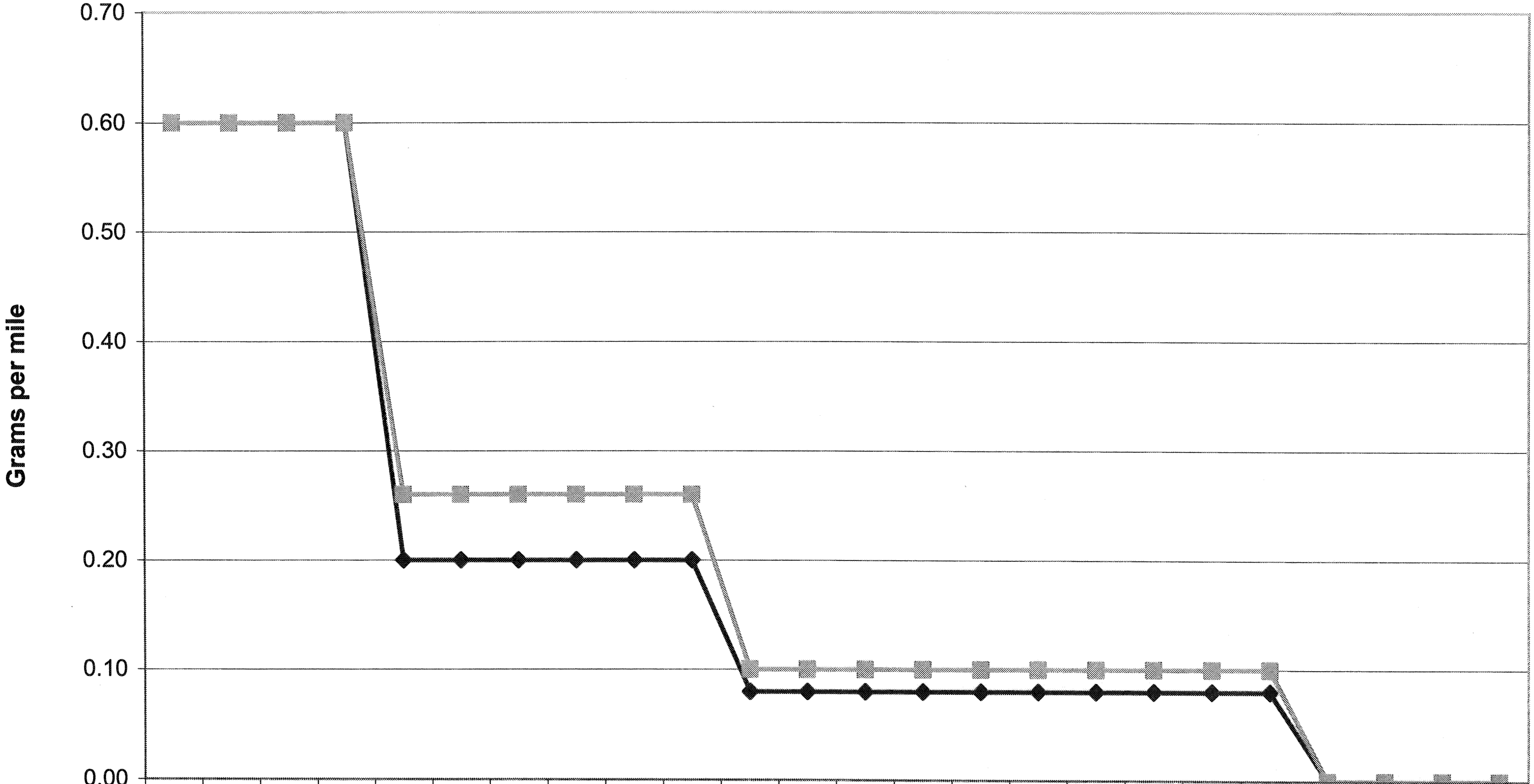


	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Pass Car	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.11	0.11	0.1	0.09	0.08	0.07	0.07
Lt Truck	1.70	1.70	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.41	0.11	0.11	0.1	0.09	0.08	0.07	0.07

Model Year

Source: Edwards and Kelcey Inc., OLO, 2003

Passenger Car and Light Truck Emission Rates by Model Year
PARTICULATE MATTER (PM)

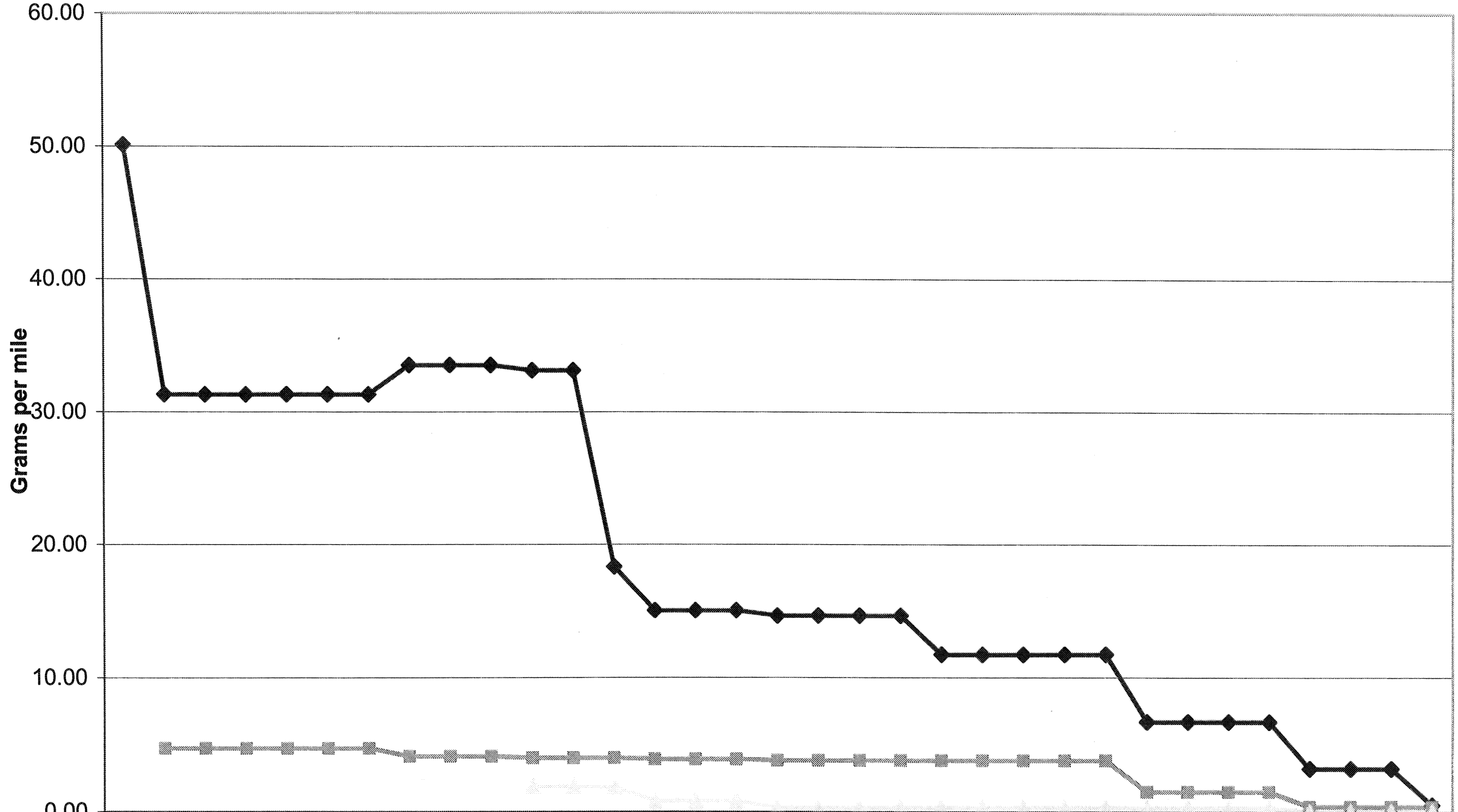


	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007-2010
Pass Car	0.60	0.60	0.60	0.60	0.20	0.20	0.20	0.20	0.20	0.20	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.00	0.00	0.00	0.00
Lt Truck	0.60	0.60	0.60	0.60	0.26	0.26	0.26	0.26	0.26	0.26	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.00	0.00	0.00	0.00

Model Year

Source: Edwards and Kelcey Inc., OLO, 2003

Heavy Duty Truck Emission Rates by Model Year
Nitrogen Oxide - Nonmethane Hydrocarbons - Particulate Matter

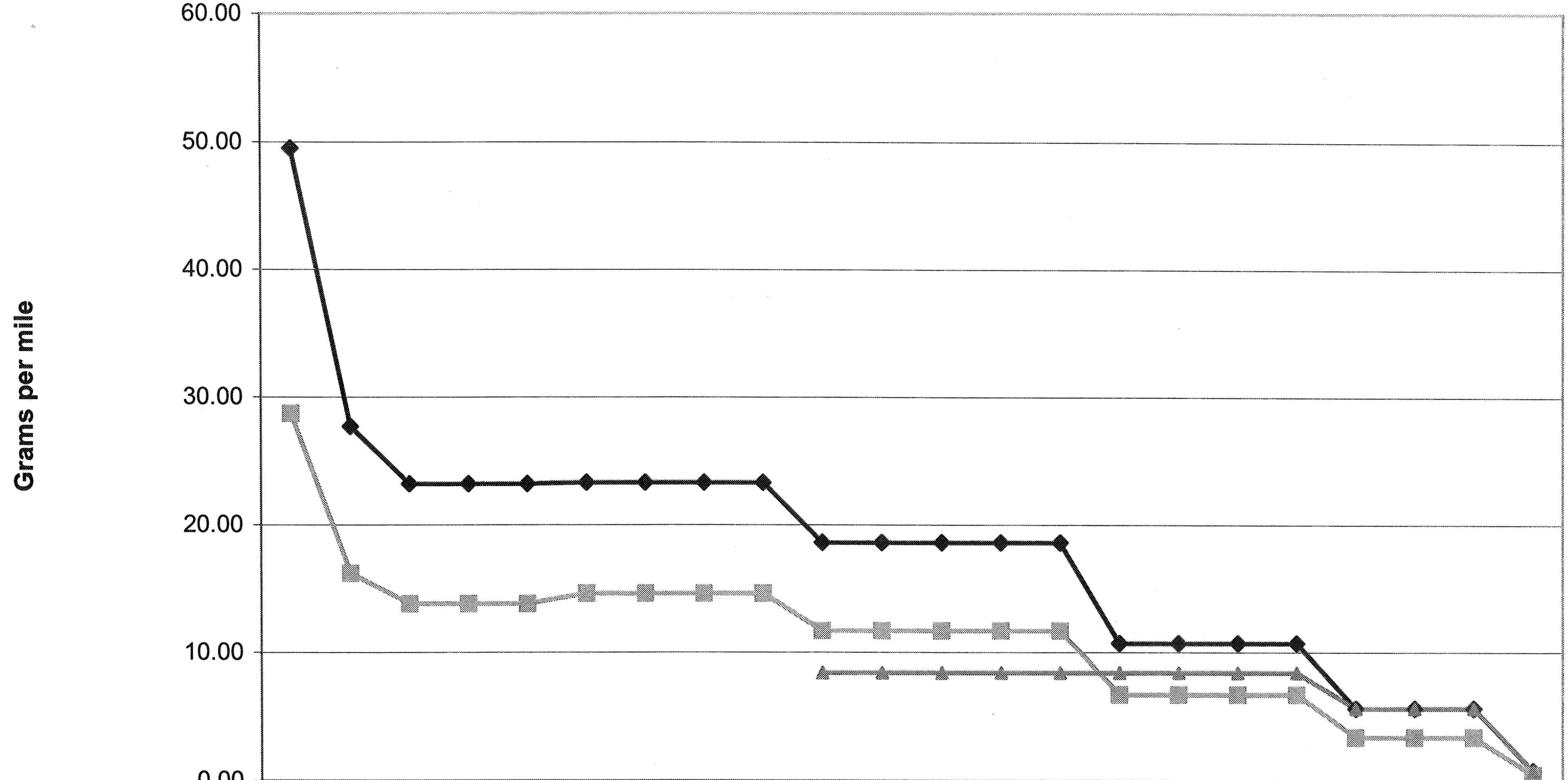


	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
NOX	50.10	31.30	31.30	31.30	31.30	31.30	31.30	33.50	33.50	33.50	33.10	33.10	18.30	15.00	15.00	15.00
NMHC		4.70	4.70	4.70	4.70	4.70	4.70	4.10	4.10	4.10	4.00	4.00	4.00	3.90	3.90	3.90
PM											1.90	1.90	1.80	0.80	0.80	0.80

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
NOX	14.60	14.60	14.60	14.60	11.70	11.70	11.70	11.70	11.70	6.70	6.70	6.70	6.70	3.20	3.20	3.20	0.50
NMHC	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	1.50	1.50	1.50	1.50	0.40	0.40	0.40	0.40
PM	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.03	0.03	0.03	0.03

Source: Edwards and Kelcey Inc., OLO, 2003

Bus Emission Rates by Model Year
NITROGEN OXIDE (NOx)

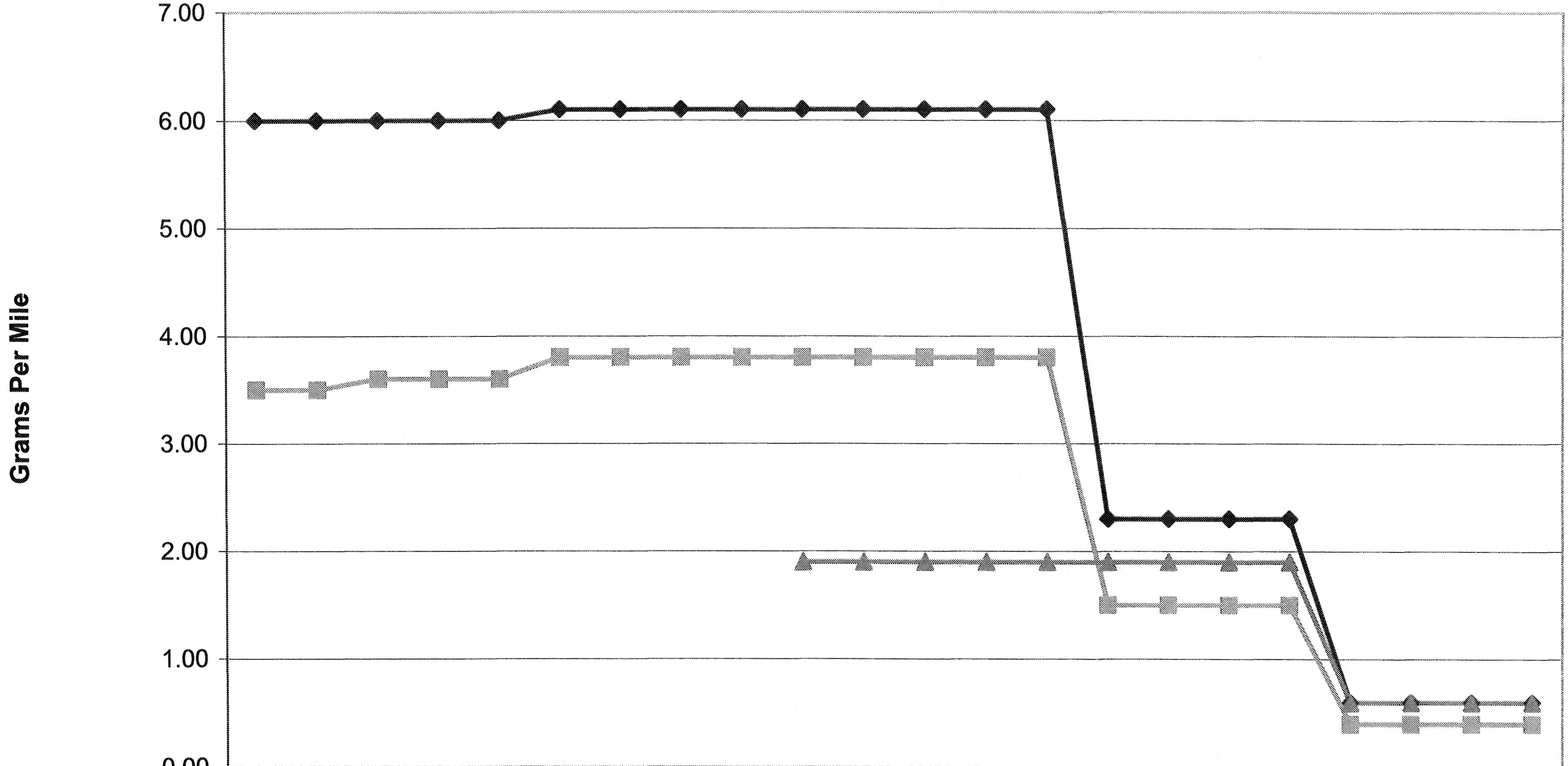


	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Diesel Transit Bus	49.50	27.70	23.20	23.20	23.20	23.30	23.30	23.30	23.30	18.60	18.60	18.60	18.60	18.60	10.70	10.70	10.70	10.70	5.60	5.60	5.60	0.80
Diesel School Bus	28.70	16.20	13.80	13.80	13.80	14.60	14.60	14.60	14.60	11.70	11.70	11.70	11.70	11.70	6.70	6.70	6.70	6.70	3.40	3.40	3.40	0.50
CNG Transit Bus										8.40	8.40	8.40	8.40	8.40	8.40	8.40	8.40	8.40	5.60	5.60	5.60	0.80

Model Year

Source: Edwards and Kelcey Inc., OLO, 2003

Bus Emission Rates by Model Year
NON-METHANE HYDROCARBONS (NMHC or VOC)

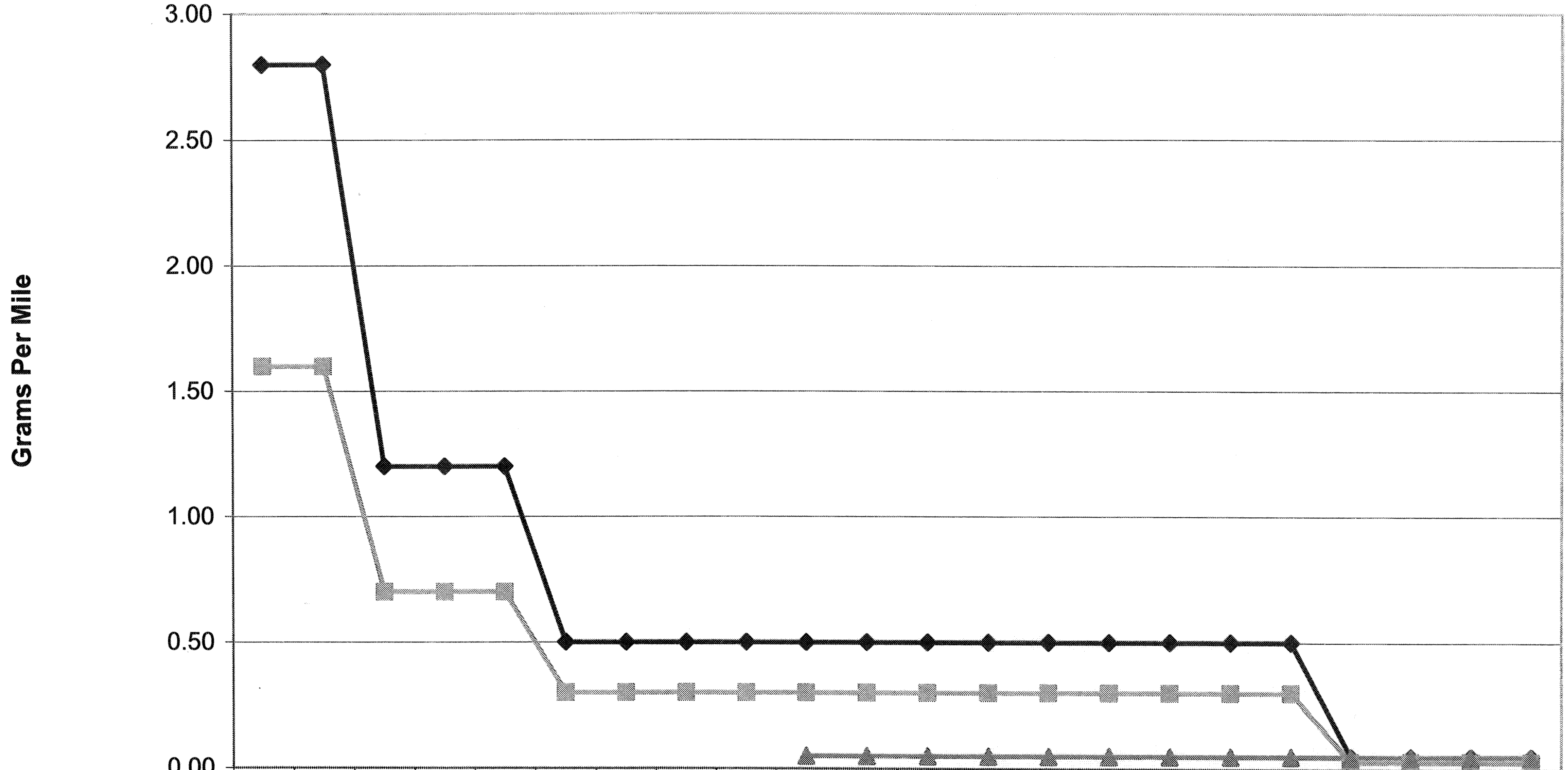


	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Diesel Transit Bus	6.00	6.00	6.00	6.00	6.00	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	6.10	2.30	2.30	2.30	2.30	0.60	0.60	0.60	0.60
Diesel School Bus	3.50	3.50	3.60	3.60	3.60	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	3.80	1.50	1.50	1.50	1.50	0.40	0.40	0.40	0.40
CNG Transit Bus										1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90	0.60	0.60	0.60	0.60

Model Year

Source: Edwards and Kelcey Inc., OLO, 2003

Bus Emission Rates by Model Year
PARTICULATE MATTER (PM)



	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Diesel Transit Bus	2.80	2.80	1.20	1.20	1.20	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.05	0.05	0.05	0.05
Diesel School Bus	1.60	1.60	0.70	0.70	0.70	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.03	0.03	0.03	0.03
CNG Transit Bus										0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05

Model Year

Source: Edwards and Kelcey Inc., OLO, 2003