Fuelling Clean Air:

Municipal Fuel Purchasing Policies that Reduce Emissions Contributing to Poor Air Quality & Climate Change

Prepared by the
Ontario Public Health Association

With Funding from

March 2003

Reference:

Ontario Public Health Association (OPHA), Fuelling Clean Air: Municipal Fuel Purchasing Policies that Reduce Air Emissions Contributing to Poor Air Quality & Climate Change, Prepared for the Greater Toronto Area (GTA) Clean Air Council, March 2003.

Author:

Kim Perrotta, Air Quality Coordinator, Ontario Public Health Association (OPHA)

Project Advisory Committee:

This project benefited greatly by the expertise & policy direction offered by the Project Advisory Committee which included:

Rob Bromley, Health Promotion Officer, Public Health Environmental Health & Lifestyle Resources, Region of Waterloo

Paul Callanan, Manager, Environmental Health, Peel Public Health, & Program Advisor, OPHA Air Quality Program.

Ken Dack, Fleets Manager, City of Brampton

Helen Doyle, Manager, Environmental Health, York Region Health Services Department, & Program Advisor, OPHA Air Quality Program.

Sarah Gingrich, Research Consultant, Health Promotion & Environmental Protection Office, Toronto Public Health, City of Toronto

Atis Lasis, Manger, Safe Environments Programme, Healthy Environments and Consumer Safety Branch, Health Canada

Eva Ligetti, Executive Director, Clean Air Partnership, & Moderator of the GTA Clean Air Council

Melinda Moriarty, Oil, Gas and Energy Branch, Environment Canada

Beatrice Olivestra, Executive Director, Friends of the Earth

Sherri Rendek, Project Manager, Clean Air Partnership

Appreciation:

The Project Advisory Committee would also like to express appreciation to the following people who offered technical background information and/or comments on early drafts of the report:

Rishi Basak, Economist, Regulatory and Economic Analysis Branch, Environment Canada

Carol Burelle, Head, In-Use Vehicle Emissions, Transportation Systems Branch, Environment Canada

Jeffrey Guthrie, Program Engineer, Oil, Gas & Energy Branch, Environment Canada

Bruce McEwen, Chief, Fuels Divisions, Environment Canada.

Greg Rideout, Head, Toxic Emissions Research and Field Studies, Emissions Research and Measurement Division, Environment Canada.

Blair Stacey, Program Engineer, Transportation Systems Branch, Environment Canada.

Mark Tushingham, Head, Fuel Processing, Fuels Division, Environment Canada

Acknowledgements:

We would like to acknowledge the support of the Walter and Duncan Gordon Foundation that funded the OPHA Air Quality Program in 2002/2003.

Distribution:

Copies of this report are available on the Clean Air Partnership website at www.toronto.ca/cleanairpartnership and on the OPHA website at www.opha.on.ca/resources/fuel.pdf.

Executive Summary

How Fuels Affect Air Quality

Hundreds of studies, conducted in countries around the world, have demonstrated that poor air quality, which results from the burning of fossil fuels, can have a profound impact on human health. While air quality is affected by a large number of air pollutants that are interacting synergistically, there are several common air pollutants that have been clearly and consistently linked to human health impacts. These include ground-level ozone, fine particulate matter (PM), sulphates (SO_4), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2). Volatile organic compounds (VOCs) and nitrogen oxides (NO_x) are frequently included in this list of common air pollutants because they are precursors of ground-level ozone.

Low sulphur fuels can improve air quality in two distinct ways. First, they directly reduce SO_2, SO_4, and PM emissions from vehicle tailpipes. Secondly, they increase the effectiveness of existing emission control devices such as oxidation catalysts, and enable the use of more advanced emission control devices such as diesel particulate filters and NO_x absorbers that are designed to reduce air pollutants such as PM, CO, VOCs, NOx and/or polycyclic aromatic hydrocarbons (PAHs).

Three Case Studies

This report examines the fuel purchasing policies established by three municipalities in Ontario to reduce air emissions from their municipal operations. In the City of Toronto, the fuel purchasing practice, which has been in place since 1999, has been designed to favour conventional fuels with lower sulphur levels. This practice, which includes purchasing on-road diesel for the City's off-road diesel fleet, has allowed the City to reduce SO_2 emissions from the City's corporate fleet from about 29.5 tonnes per year in 1999 to about 6 tonnes per year in 2003. Over the three years that the City has been purchasing on-road diesel for its off-road fleet, it has paid between 2.7% less and 5.7% more per litre for the red dyed on-road diesel than it would for the cheapest off-road diesel. Overall, however, the City has paid about 1% more each year for its fuel to achieve the emission reductions described above.

In 2003, the Region of Waterloo will begin implementing the top three recommendations contained in the Region's Clean Air Plan by purchasing: 1) on-road diesel for the Region's off-road diesel fleet; 2a) ultra low sulphur diesel (ULSD) for the Region's buses; 2b) catalytic exhaust mufflers (CEM) for 86 of the Region's 143 buses; and 3) E10 (10% ethanol blended with 90% gasoline) for the Region's gasoline-fuelled fleet. The use of on-road diesel for the Region's off-road fleet is expected to reduce emissions of sulphur oxides (SO_x) by about 8.5 tonnes per year; while the use of ULSD in buses is expected to reduce SO_x emissions by about 2.8 tonnes per year. The retrofitting of buses with CEMs is expected to reduce emissions of CO, VOCs, and PM by about 17 tonnes per year. In 2003, the Region expects to pay about $0.04 (or 6.5%) more per litre for the ULSD than it would for conventional on-road diesel.

The City of Brampton began purchasing B20 (20% biodiesel blended with 80% on-road diesel) for use in the City's Corporate on- and off-road diesel fleets in 2002, and plans, in 2003, to use: 1) B20 in the City's bus system; 2) B100 (100% biodiesel) in the City's Corporate on-road and off-road diesel fleets during the summer months; and 3) E10 in the City's gasoline fleet. By using B20 that has been blended with on-road diesel in the City's off-road diesel fleet, it is expected that the City will reduce SO_2 emissions from that fleet by about 88% (or by about 1 tonne per year). The use of B20 in the City's Corporate on-road diesel fleet is expected to reduce SO_2 emissions from that fleet by about 20%. The use of B20 is also expected to reduce emissions of CO, PM and HC. In 2002, B20 cost the City of Brampton about $0.04 (or 6.5%) more per litre than conventional on-road diesel, but in 2003, the City expects the cost differential to increase to as much as $0.12 per litre (or 20% more).

Lowering Emissions from Gasoline Fuelled Vehicles

Among the three municipalities, two approaches were examined for lowering emissions from gasoline fuelled vehicles:

a) favouring gasoline with the lowest sulphur levels; and
b) purchasing E10 (10% ethanol blended with 90% gasoline).

With sulphur levels in gasoline predicted to come down to 30 ppm in Ontario by the fall of 2003, there is no reason why any municipality should buy gasoline with sulphur levels greater then 30 ppm after that date. By purchasing gasoline that contains 30 ppm sulphur many municipalities could reduce SO_2 emissions from their gasoline fuelled fleets by about 92% relative to 2001.

Some municipalities may want to purchase 30 ppm sulphur gasoline that has been blended with ethanol. While the air quality benefits associated with ethanol's use in Canadian gasoline remains unclear, ethanol's production does appear to reduce greenhouse gas emissions. Currently, E10 can be purchased at the same price as conventional gasoline because of tax breaks.

Lowering Emissions from Off-Road Diesel Vehicles

From a fuels perspective, the biggest air quality impacts can be achieved by shifting away from the use of off-road diesel which contains between 1,300 and 3,700 ppm sulphur. The options considered by one or more of the three municipalities include shifting to:

a) conventional on-road diesel that contains 278 to 440 ppm sulphur;
b) ultra low sulphur diesel (ULSD) that contains 15 ppm sulphur; and
c) B20 (20% biodiesel with 80% on-road diesel) that contains up to 20% less sulphur than conventional on-road diesel.

The conventional on-road diesel option (option a), which could reduce SO_2 emissions from a municipality's entire corporate fleet by as much as 90%, is the least expensive option. ULSD could further reduce SO_2 emissions, but would also increase costs by about 6.5% beyond that for conventional on-road diesel. The B20 option would reduce SO_2 emissions by less than ULSD option, but could also reduce CO, PM and HC emissions from older vehicles without requiring modifications, and would produce climate change benefits.

It can, however, increase costs by 6.5 to 20% beyond that for conventional on-road diesel.

Lowering Emissions from On-Road Diesel Vehicles

With on-road diesel fleets, the options considered by one or more of the three municipalities examined include:

a) Selecting conventional diesel with the lowest sulphur levels;
b) Retrofitting buses with catalytic exhaust mufflers (CEM);
c) Using ULSD in buses and/or the Corporate fleet;
d) Using ULSD & retrofitting buses with CEMs;
e) Using B20 in buses and/or in the Corporate fleet; and
f) Using B100 biodiesel in the Corporate fleet in summer months.

Given that sulphur levels in on-road diesel in Ontario ranged from 278 to 437 ppm in 2001, substantial air quality benefits can be gained by simply favouring the supplier with the lowest sulphur levels, as the City of Toronto has done.

Significant air quality benefits appear to be associated with both, the retrofitting of older buses with CEMs, and the rebuilding of bus engines with electronic engine controls. Demonstration studies suggest that CEM retrofits can reduce emissions of PM, CO and NOx by up to 34%, 74% and 3.8% respectively, for a cost of about $3,200 to $5,000 per bus. When older buses are rebuilt with electronic engine controls and retrofitted with CEMs, estimates suggest that emissions of PM, CO and NOx can be reduced by up to 92%, 74% and 33% respectively, for a cost of $20,000 to $50,000 per bus. This latter approach can also reduce fuel costs and CO_2 emissions by about 8% by increasing the vehicle's fuel efficiency by about 8%.
When ULSD is used in corporate on-road diesel vehicles or buses run by transit authorities, SO_2 emissions can be reduced by about 95%. More importantly, when ULSD is used in vehicles equipped with oxidation catalysts, emissions of CO, PM, SO_4 and PAHs can be reduced by an additional 35%, 15%, 92% and 15% respectively. ULSD is also essential with the use of more advanced emission control technologies such as continuously regenerating diesel particulate filters (CR-DPF) which can produce significant reductions in a broad array of air pollutants.

An analysis conducted by the U.S. EPA suggests that B20's use in heavy-duty on-road diesel vehicles can reduce emissions of CO and PM by about 11% and 10% respectively, while increasing NOx emissions by about 2%. These impacts vary however, depending upon the model year of the engine, the source of the biodiesel (eg. plant or animal based), and the properties of the conventional diesel with which the biodiesel has been blended. B20 is also expected to reduce SO_2 emissions by up to 20% and to produce substantial climate change benefits. B20 has the disadvantage of reducing fuel economy by about 2%, and of being subject to widely varying price swings.

Neat biodiesel (B100) has the potential to produce significant air quality and climate change benefits. On the other hand, B100 can increase emissions of NO_x by about 10% and can reduce fuel economy by between 8 to 10%. It also has the disadvantage of being expensive at present.

Recommendations

To reduce air emissions that contribute to poor air quality, municipalities should amend their fuel purchasing practices to ensure that they purchase on-road diesel for their off-road diesel fleets, and, beginning the fall of 2003, gasoline that contains 30 ppm sulphur. They may want to consider having this low-sulphur gasoline blended with ethanol, and the on-road diesel blended with biodiesel, to produce climate change benefits. They should also consider using ULSD and/or B20 in their corporate on-road diesel fleets.

Municipalities should examine their transit fleets to determine the financial costs and emission benefits associated with rebuilding engines with electronic engine controls, retrofitting older vehicles with catalytic exhaust mufflers (CEMs), and using ULSD.

The GTA Clean Air Council should explore:

a) the ownership of emissions trading credits created as a result of fuel purchasing policies;

b) the benefits of, and mechanisms available for, pooling the fuel purchases of partners of the GTA Clean Air Council; and

c) establishing a Green Fleets Subcommittee to monitor developments related to fuels, vehicles and emission control technologies.

Glossary of Terms

Biodiesel
Fuel derived from plant oils or animal fat that can be used with, or in place of, conventional petroleum-based diesel fuel.

CO Carbon monoxide, a gaseous air pollutant

CO_2 Carbon dioxide, a greenhouse gas

Ethanol
An alcohol fuel that is commonly made from corn or sugar but can be made from any feedstock containing appreciable amounts of sugar. Can be mixed with, or used in place of, gasoline.

HC Hydrocarbons, air pollutants and precursors of smog

NO_x Nitrogen oxides, gaseous and particulate air pollutants and precursors of smog

NO_2 Nitrogen dioxide, a gaseous air pollutant and precursor of smog

On-Road Diesel
Diesel fuel that is used in municipal vehicles that are licensed for use on road (often called "clear diesel" or "low sulphur diesel")

Off-Road Diesel
Diesel fuel that is used in engines and vehicles that are not licensed for use on roads (often called "red diesel"). The off-road diesel fleet of municipalities can include back loaders, large lawn mowers, back-hoes, sidewalk clearers, asphalt machines, and in a city such as Toronto, ferries.

PAHs Polycyclic aromatic hydrocarbons, toxic air pollutants

PM Fine particulate matter including PM_{10} and $PM_{2.5}$

PM_{10} Fine particulate matter with diameter less than 10 microns

$PM_{2.5}$ Fine particulate matter with diameter less than 2.5 microns

Smog When tightly defined, includes ground-level ozone and fine particulate matter. When loosely defined, smog includes several air pollutants commonly present in the air as a result of the incomplete combustion of fossil fuels that contribute to human health impacts (i.e. CO, SO_2, SO_4, PM, ozone, NO_2).

SO_2 Sulphur dioxide, a gaseous air pollutant and precursor of smog

SO_4 Sulphate, a particulate air pollutant

THC Total hydrocarbons, air pollutants and precursors of smog

VOCs Volatile organic compounds, air pollutants and precursors of smog

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Introduction

This report represents a preliminary examination of fuel purchasing practices that can be adopted by local or regional governments to reduce air emissions that contribute to poor air quality and/or global climate change. It has been prepared by the Ontario Public Health Association (OPHA) for the GTA Clean Air Council with project-specific funding provided by The Clean Air Partnership and with general funding provided by the Walter and Duncan Gordon Foundation.

The GTA Clean Air Council is an inter-governmental working group dedicated to exploring joint clean air initiatives and liaising with municipalities across Canada to discover best practices for reducing smog. The Council currently has members representing 15 cities and towns and 4 regions in the Greater Toronto Area (GTA) as well as partners from the federal and provincial governments. At the Smog Summit convened in Toronto in June 2002, the GTA Clean Air Council partners committed to "researching and developing a low sulphur fuel purchasing standard" that could be adopted by all GTA Clean Air Council partners by June 2003.

The primary goal of this report is to provide the GTA Clean Air Council with information, policy analysis, and recommendations to assist in the development of a low sulphur fuel-purchasing standard. It also evaluates ethanol and biodiesel blended fuels as non-conventional fuels that might be used as alternatives to, or in combination with, conventional low sulphur fuels. This report does not address any fuels or technologies that would require expensive modifications to existing vehicles or infrastructure (i.e. it does not evaluate natural gas as an alternative fuel). Nor does it provide a comprehensive analysis of all fuel combinations that are currently available on the market. This report is divided into five sections:

Section I provides a brief summary of the health impacts associated with poor air quality and the health benefits associated with low sulphur fuels;

Section II summarizes the regulatory requirements that apply to sulphur levels in fuels and the sulphur levels in conventional gasoline, on-road diesel and off-road diesel that is currently refined in or imported into Ontario;

Section III summarizes the fuel purchasing practices established by three municipalities in Ontario to reduce air emissions from municipal operations;

Section IV evaluates the different strategies selected by the three municipalities for their gasoline, on-road diesel and off-road diesel fleets, and involves some discussion of ethanol blended gasoline and biodiesel blends as well as low sulphur fuel options;

Section V provides a summary of the different strategies and provides recommendations for consideration by the GTA Clean Air Council.

I. Health Arguments: Low Sulphur Fuel Policies

Air Quality and Public Health

Hundreds of studies conducted in countries around the world have demonstrated that poor air quality, resulting from the burning of fossil fuels, can have a profound impact on human health. Numerous studies have demonstrated that short-term exposure to spikes in air pollution are associated with increases in: premature deaths, hospital admissions for cardiovascular and respiratory disease, asthma symptoms, and respiratory infections such as bronchitis and pneumonia (NAAQO, 1999a/b; TPH, 2000a/b; OMA, 1998).

While the majority of air quality studies have been directed at acute health effects associated with short-term exposure to increased levels of pollution, more recent studies have been directed at the chronic health effects associated with long-term exposure to lower levels of air pollution. These studies indicate that air pollution contributes to the development of chronic heart and lung diseases including cancer and asthma.

For example, a team of researchers that followed 1.2 million adults in the United States over a 16-year period found a strong and consistent link between air levels of respirable particulate matter ($PM_{2.5}$), sulphates (SO_4) and sulphur dioxide (SO_2), and deaths from lung cancer, cardio-pulmonary illnesses, and all causes of death. They concluded that air pollution in some U.S. cities presents a health risk comparable to that presented by long-term exposure to second hand smoke (Pope et al., 2002).

In another example, a ten year study conducted by the University of Southern California found that children who live in high ozone communities and play three or more sports develop asthma at a rate three times higher than those in low ozone communities (Gauderman et al., 2002).

While a mounting body of evidence suggests that air pollution can affect all members of society, children, the elderly and those with predisposing respiratory conditions (such as asthma) or heart conditions (such as congestive heart failure) appear to be most vulnerable (OMA, 1998; Burnett et al., 2001).

Air Pollution Burden of Illness

The Ontario Medical Association (OMA) has estimated that the acute health effects associated with fine particulate matter and ground-level ozone in Ontario cost at least $1 billion per year in direct costs for hospital admissions, emergency room visits and absenteeism. These costs do not reflect the costs associated with medication or visits to doctors' offices, which the OMA expects would be significant. The OMA has further estimated that the pain, suffering and loss of life associated with air pollution "costs" Ontario citizens another $9 billion per year (OMA, 2000).

Air Pollutants of Concern

While air quality is affected by a large number of air pollutants interacting synergistically, there are several common air pollutants that have been clearly and consistently linked to the health impacts identified above. These include ground-level ozone, fine particulate matter (PM), sulphates (SO_4), carbon monoxide (CO), nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) (TPH, 2001a/b).

Ozone, Nitrogen Oxides & Volatile Organic Compounds

Ground-level ozone is the air pollutant responsible for most of the smog alerts declared in Ontario. It is a secondary air pollutant formed in the air by a reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. Because sunlight is needed for the reaction, air levels of ozone are also related to the weather, and are higher in the summer months in Canada.

Fine Particulate Matter

Fine particulate matter is the solid or liquid particles in the air that are small enough to be inhaled, and can include acid aerosols such as sulphates, metal fumes, organic chemicals, pollen and smoke. Inhalable particulate matter (called PM_{10}) is the term used for those particles that are less than 10 microns in diameter while respirable particulate matter (called $PM_{2.5}$) is the term used for those particles less than 2.5 microns in size.

Recent studies suggest that respirable particulate matter is the most damaging to human health because it can penetrate so deeply into the lungs. In fact, the Federal Provincial Working Group on Air Quality Objectives and Guidelines has concluded that the health impacts associated with $PM_{2.5}$ may be twice as high as those associated with PM_{10}, and that the health impacts may even be greater for sulphates (NAAQO, 1999b).

Carbon Monoxide, Nitrogen Dioxide, & Sulphur Dioxide

Several studies conducted on different continents in recent years have suggested that the gaseous air pollutants also have a significant direct impact on human health. For example, a 1998 study demonstrated that NO_2, SO_2, CO and ozone were responsible for 4.1%, 1.4%, 0.9% and 1.8% respectively of all premature deaths in eleven different cities in Canada including Toronto, Ottawa, Hamilton, London and Windsor. Combined, these gaseous air pollutants were responsible for, on average, 7.7% of all premature deaths in these eleven cities (Burnett, 1998).

Low Sulphur Fuels Reduce Emissions in Two Ways

Low sulphur fuels improve air quality in two distinct ways. First of all, there is a linear relationship between sulphur levels in fuels and SO_2 emissions from vehicle tailpipes. When sulphur levels in fuels are reduced by 90%, it can be crudely estimated that tailpipe emissions of SO_2 will be reduced by about 90%. While SO_2 is a gas that has been directly associated with respiratory impacts in a number of studies, it is also the precursor of sulphates, which have been clearly and consistently associated with respiratory and cardiovascular impacts in a large number of studies (TPH, 2000a). Sulphates are also a significant component of PM_{10} and $PM_{2.5}$. The Ontario Ministry of the Environment estimates that 25% of PM_{10} and 40% of $PM_{2.5}$ in Ontario's air are sulphates (TPH, 2000a).

Secondly, ultra low sulphur fuels are "enablers" that: 1) allow greater reductions in emissions of PM, HC, VOCs and NOx with existing emission control devices such as oxidation catalysts; and 2) are required for the use of advanced emission control devices such as diesel particulate filters (DPF) and NOx absorbers (Env Can, 2001; Panel, 1997).

Health Benefits Associated with Low Sulphur Fuels

In 1997, the Health and Environmental Impact Assessment Panel (HEIAP) was struck by the Government of Canada to assess the health benefits that would be associated with regulations that established a "minimum national standard" for sulphur levels in Canadian fuels. The Panel estimated the health impacts of nine sulphur scenarios using sulphates as the indicator pollutant for all health impacts avoided. The Panel acknowledged that this methodology likely underestimates the total health benefits associated with each scenario (HEAIP, 1997).

Table 1 below provides the Panel's estimates of the health impacts that could be avoided in seven Canadian cities over a 20-year period for three of the nine sulphur scenarios assessed. The most significant health benefits were associated with the 30 ppm gasoline standard, followed by the 400 ppm off-road diesel standard, and then the 50 ppm on-road diesel standard. It was determined that the avoided health impacts would be greatest in the Toronto area because of: 1) the high sulphur levels in Ontario fuels; 2) the high number of vehicle miles travelled in the Toronto area; and 3) the large size of the population affected (4 million people)(HEIAP, 1997)

The Panel estimated the economic value of the avoided health impacts and determined that, over a 20-year period, in the seven Canadian cities, the 30 ppm gasoline scenario could produce health benefits worth $7.2 billion, while the 50 ppm on-road diesel standard would produce health benefits worth $1.7 billion, and the 400 ppm off-road standard could provide health benefits worth $4.0 billion (HEIAP, 1997).

Table 1 **Health Impacts Avoided with Sulphur Fuel Standards, in 7 Canadian Cities, Over 20 years, Number of Cases**

Avoided Effect	Gasoline 30 ppm	On-Road Diesel 50 ppm	Off-Road Diesel 400 ppm
Premature Mortality	1,352	318	756
Chronic Respiratory Disease Cases	4,770	1,120	2,660
Respiratory Hospital Admissions	848	200	474
Cardiac Hospital Admissions	689	162	385
Emergency Room Visits	4,294	1,013	2,398
Asthma Symptom Days	2,086,511	492,368	1,166,348
Restricted Activity Days	993,134	234,692	555,571
Acute Respiratory Symptoms	7,159,671	1,687,922	3,999,816
Lower Respiratory Illness (Children)	58,429	14,136	32,984

Source: HEIAP, 1997 [revised 1998]

Transportation Sector is a Significant Contributor

In Ontario, the transportation sector is the greatest contributor of both of the precursors of ground-level ozone and of CO. In 2000, on-road and off-road vehicles were responsible for about 30% of the VOCs, 63% of the NOx, and 66% of the CO emitted in Ontario (MOE, 2001).

While large point sources such as smelters and coal-fired power plants are the most significant sources of SO_2 and PM in the province, the transportation sector can be an important source of these air pollutants in an urban airshed (MOE, 2001). For example, within the City of Toronto, it has been estimated that the transportation sector is responsible for about 60% of SO_2 emissions (Bell, 2003).

Fleets Responsible for Significant Portion of Municipal Emissions

The Corporate Fleets operated by municipal governments can be responsible for a significant portion of the air pollutants emitted from municipal operations. For example, when the Region of Waterloo estimated the air emissions associated with Regional operations, it determined that the Region's on-road and off-road vehicles were responsible for about 63% of the NO_x, 12% of the SO_x, 97% of the CO, 96% of the VOCs, and 77% of the PM_{10} emitted from Regional operations (Region of Waterloo, 2002, p.13).

II Sulphur Standards & Levels for Canadian Fuels

Sulphur Levels in Gasoline

The *Sulphur in Gasoline Regulations* were passed by the federal government in June 1999. These regulations will limit the sulphur content in gasoline to an average of 30 ppm, with a maximum of 80 ppm, starting in January 2005. They also establish an interim average limit of 150 ppm for sulphur in gasoline between July 2002 and December 2004 (Env Can, 2002).

While sulphur levels are expected to be reduced at different rates by different companies, Environment Canada expects most refineries in Ontario to reduce sulphur levels in their gasoline to 30 ppm by the fall of 2003 in order to meet the required average limit of 150 ppm over the 2.5 year interim period (Tushingham, 2003).

In 2001, sulphur levels in gasoline produced or imported in Ontario averaged 390 ppm and ranged from 180 to 596 ppm *(See Table 2 below)*(Env Can, 2002).

Table 2 **Sulphur Levels (ppm) in Gasoline, by Refinery or Importer, 2001**

Imperial Oil *Sarnia*	Imperial Oil *Nanticoke*	Shell *Sarnia*	Petro Canada *Oakville*	Sunoco *Sarnia*	*Petro Canada *Oakville*	*Olco *Hamilton*
596	376	462	396	180	368	317

(Volume Weighted, Annual Average)
* selected importers

Source: Env Can, 2001

On-Road & Off-Road Diesel Fuels

There are two types of diesel fuel used by municipal governments. There is the diesel fuel that is used in vehicles that are licensed for use on roads, and there is the diesel fuel that is used in engines and vehicles that are not licensed for use on roads. Municipal off-road diesel fleets can include back loaders, large lawn mowers, back-hoes, sidewalk clearers, asphalt machines, and in a city such as Toronto, ferries. The fuel used in on-road vehicles, which is often called "clear diesel" or "low sulphur diesel", will be referred to as "on-road diesel" in this report, while the fuel used in off-road equipment, which is often called "red diesel" will be referred to as "off-road diesel".

Sulphur Levels in On-Road Diesel

The Canadian federal *Diesel Fuel Regulations*, which came into effect in January 1998, required that all on-road diesel have sulphur levels below 500 parts per million (ppm). However, in July 2002, the federal government revoked those regulations, replacing them with the *Sulphur in Diesel Fuel Regulations*. These new regulations will continue the 500 ppm maximum until the middle of 2006, at which time the limit will be reduced to15 ppm (McEwen, 2003).

The new Regulations are designed to align Canadian requirements for on-road diesel with new U.S. Rules that were promulgated in January 2001. The U.S. Rules, which address the specifications for both fuels and vehicles, will require the use of high-efficiency catalytic exhaust emission control devices, particulate filters, and other technologies in heavy-duty on-road vehicles, and the lowering of sulphur levels in on-road diesel from 500 ppm to 15 ppm. They are expected to decrease emissions of PM and NOx by 90% and 95% respectively. In the United States, the new Rules will be phased in between 2007 and 2010 (Clean Air Independent Review Subcommittee, 2002).

In 2001, sulphur levels in on-road diesel produced or imported in Ontario averaged 360 ppm and ranged from 278 to 437 ppm *(see Table 3 below)* (Env Can, 2001).

Table 3 **Sulphur Levels (ppm) in On-Road Diesel, by Refinery or Importer, 2001**

Imperial Oil *Sarnia*	Imperial Oil *Nanticoke*	Shell *Sarnia*	Petro Canada *Oakville*	Sunoco *Sarnia*	*Robbins *Oakville*	* Sunoco *Sarnia*
349	356	392	278	437	289	430

(Volume Weighted, Annual Average)
* selected importers

Source: Env Can, 2001

Sulphur Levels in Off-Road Diesel

Existing federal regulations limit sulphur levels in off-road diesel fuels to a maximum of 5,000 ppm. The U.S. EPA is currently drafting new rules to reduce emissions from off-road vehicles and machinery by 95%. These new rules are expected to cut sulphur content in off-road diesel to 15 ppm by 2010 while giving vehicle manufacturers until 2012 to comply with the new vehicle emission standards (Pianin, 2002). In Canada, the February 2001 Notice of Intent on Cleaner Vehicles, Engines and Fuels stated the federal government's intention to develop sulphur limits for off-road diesel fuel in the same time frame as the United States (McEwen, 2003).

In 2001, sulphur levels in off-road diesel produced or imported in Ontario averaged 2,890 ppm and ranged from 1,297 to 3,676 ppm *(see Table 4 below)* (Env Can, 2001).

Table 4 **Sulphur Levels (ppm) in Off-Road Diesel, by Refinery or Importer, 2001**

Imperial Oil *Sarnia*	Imperial Oil *Nanticoke*	Shell *Sarnia*	Petro Canada *Oakville*	Sunoco *Sarnia*	*Petro *Canada Oakville*	* Olco *Hamilton*
1297	N/R	3676	2839	2291	2812	N/R

(Volume Weighted, Annual Average)
* importers

N/R: Not Reported

Source: Env Can, 2001

III: Fuel Purchasing Policies that Reduce Air Emissions

Three Municipalities - Overview

We have identified three municipalities in Ontario that have adopted fuel purchasing policies or practices designed to reduce air emissions associated with the operation of the municipality's fleet of vehicles.

In the City of Toronto, the fuel purchasing practice, which has been in place for five years, has been designed to favour fuels with lower sulphur levels, and has resulted in the purchasing of on-road diesel for the City's off-road diesel fleet.

In the Region of Waterloo, the fuel and vehicle purchasing plan is an integrated part of an overall Clean Air Plan developed in 2002. Under this plan, the Region will be purchasing: 1) on-road diesel for the Region's off-road diesel fleet; 2a) ultra low sulphur diesel (ULSD) for the Region's buses; 2b) catalytic exhaust mufflers (CEM) for 86 of the Region's 143 buses; and 3) E10 (10% ethanol blended with 90% gasoline) for the Region's gasoline fuelled fleet.

In the City of Brampton, the fuel purchasing practice involves the use of: a) B20 (20% biodiesel blended with 80% on-road diesel) in the City's Corporate on-road and off-road diesel fleets; and in 2003, will involve the use of: b) B20 in the City's bus system; c) B100 (100% biodiesel) in the City's Corporate on-road and off-road diesel fleets during the summer months; and d) E10 in the City's gasoline fleet.

Case #1: City of Toronto — Low Sulphur Fuel Corporate Purchasing Practice

Overview & Rationale

In 1999, as a means of reducing corporate emissions that contribute to poor air quality, the City of Toronto adopted a practice of "considering sulphur levels in fuel as well as costs" when awarding contracts for the City's gasoline and on- and off-road diesel fuels (TPH, 2001).

The City's Tender has been amended such that, refineries submitting bids to provide the City's fuel must report their annual average sulphur levels for the different fuel types. Each year, the City's bids are evaluated both in terms of costs and potential reductions in SO_2 emissions. For each fuel type, contracts have been awarded to the bidder with the lowest prices where sulphur levels are similar, and to the bidder with the lowest sulphur levels where the cost differential is deemed reasonable (TPH, 2001).

Since 2000, the City has purchased its gasoline from Sunoco because its gasoline has contained about 40-60% less sulphur than the gasoline provided by other bidding companies. Since 2001, the City has been purchasing on-road diesel for its off-road fleet when it determined that the taxes that apply to on-road diesel do not apply when on-road diesel is used in off-road vehicles.

The low sulphur fuel purchasing practice applies to the on-road and off-road vehicles/engines in the City's Corporate fleet. The fuel choices made for the Corporate Fleet often influence the fuel choices made by the Toronto Transit Authority and other agencies, boards and commissions of the City.

Emissions Reductions and Costs

The City's low sulphur fuel purchasing practice is expected to reduce emissions from the City's Corporate fleet in two ways: 1) By reducing emissions of SO_2 and sulphate/PM from all vehicles using low sulphur fuels; and 2) By reducing emissions of CO, NOx and VOCs from those vehicles that are equipped with oxidation catalysts (i.e. most light-duty gasoline vehicles) which operate more efficiently when SOx emissions are reduced.

For simplicity's sake, the City has used estimates of SO_2 emissions alone to estimate the emissions reductions associated with its fuel purchases over the last five years, and has assumed that all sulphur in the fuel would be emitted as SO_2, when in fact, some portion would be emitted as other sulphur compounds.

It has been estimated that the City's low sulphur fuel purchasing practice has decreased SO_2 emissions from the City's Corporate Fleet from about 29.5 tonnes per year in 1999 to about 6 tonnes in 2003 (see Table 5). The emissions reductions from the City's off-road fleet have been responsible for nearly 90% of these reductions (see Table 5). Over the three years that the City has been purchasing on-road diesel for its off-road diesel fleet, it has paid between 2.7% less and 5.7% more per litre for the red dyed on-road diesel than it would for the cheapest off-road diesel (Gingrich, 2003; Perrotta, 2003). Overall, however, the City has paid about 1% per year more for its fuel than it would have if it had purchased fuel from suppliers offering the lowest prices.

Table 5 **SO_2 Emissions (kg), Corporate Fleet Toronto, 1999 - 2003**

Year	On-Road Diesel Fleet	Off-Road Diesel Fleet	Gasoline Fleet	Total Fleet	% Increase in Cost Relative to Low Cost Bid
1999	4,165	22,950	2,550	29,665	
2000	4,420	11,560	1,530	17,510	+1.20
2001	5,015	2,380	1,275	8,670	+0.85
2002	4,890	1,577	1,126	7,600	+1.07
2003	3,154	1,609	1,234	6,000	+0.92

Source: Data for 2000/2001 derived from TPH, 2001 and corrected for fuel density.
Data for 2002/2003 derived from Toronto Purchasing & Material Management, 2001 & 2002

Equation Used to Estimate SO_2 Emissions

For simplicity's sake, the emissions associated with each bid and fuel type have been crudely estimated by applying the following equation:

Total SO_2 = [ppm S in fuel] x [litres of fuel] x [fuel density] x [MW of SO_2/AW of S] x 1 kg/1,000,000 mg

Where: Sulphur content is ppm by weight (mg S/kg fuel)
Fuel density (kg/L) is approximately 0.734 for gasoline & 0.844 for on-road diesel and off-road diesel in Ontario
MW (molecular weight) of SO_2 is 64
AW (atomic weight) of sulphur is 32
1000 kg = 1 tonne

Note: Sulphur levels and fuel densities can be found in the annual reports, "Sulphur in Liquid Fuels", published by Environment Canada.

Quantities Purchased

In 2003, the City's fuel purchasing practice applied to approximately:

- 3.5 million litres of gasoline,
- 6.9 million litres of diesel for its on-road fleet, and
- 2.4 million litres of diesel for its off-road fleet (Gingrich, 2003).

Technical Considerations/Concerns

Comparing fuels based on annual average sulphur levels at the refinery gives a good picture of a refinery's output and assurances that a refinery can deliver the selected product. However, this approach does not allow the City to award contracts based on refineries' promises of future reductions in sulphur levels, or on improvements made in the very recent past (Gingrich, 2003).

Fleet Management Services supported the increased expenditure for low sulphur fuel in 1998 on the belief that lower sulphur levels would decrease fleet maintenance costs.

Under the provincial tax rules, off-road diesel must be dyed red in order to be eligible for the tax breaks that apply to fuels used in off-road vehicles. Therefore, when on-road diesel is purchased for use in off-road vehicles, it must be dyed red by the supplier in order to be excluded from the taxes that would ordinarily apply to on-road diesel.

Non-Conventional Fuels Being Piloted

The City of Toronto used neat biodiesel (100% biodiesel) in one of its garbage trucks, as a pilot project in 2002, and encountered no difficulties.

The City also owns and operates a number of natural gas vehicles.

In 1998, the City decided not to use ethanol blended gasoline because of concerns respecting: 1) reduced fuel efficiency; 2) increased emissions of aldehydes; and 3) uncertainties respecting climate change impacts (Perrotta, 2003).

Emissions Credits

The City is currently doing background research on emissions trading and the creation of emissions credits to determine how best to address this issue within the context of the fuel tender.

Departments Involved

This practice is implemented each year by a collaborative process between Toronto Public Health, Purchasing and Materials Management, Works & Emergency Services and Fleet Management Services.

Contact

Sarah Gingrich, Research Consultant, Toronto Public Health, sgingri@toronto.ca

Case #2: Region of Waterloo – Fuel & Vehicle Purchasing Plan

Overview & Rationale

In 2002, the Region of Waterloo Public Health Department prepared a report, "Discussion Paper for Clean Air Plan", that assessed the emissions impacts and costs of various policy options that could be adopted by the Region to address poor air quality. Among the eleven policies identified as "top" priorities were three directed at the Region's Corporate Fleet of vehicles.

It was decided that the Region should: 1) Replace gasoline with E10 (a 10% ethanol/ 90% gasoline blend); 2) Replace off-road diesel used in the Corporate fleet with on-road diesel; 3a) Purchase ultra-low sulphur diesel (ULSD) that contains 15 ppm sulphur for the Region's buses; and 3b) Retrofit 86 of the Region's older buses with catalytic exhaust mufflers (CEM). The staff have also recommended to Council that the Region purchase buses equipped with continuously regenerating diesel particulate filters (CR-DPF) as old buses are retired over the next 10 years (Bromley, 2003). The Region has captured the non-conventional fuels in its Tender by adding an alternative fuels section.

Emissions Reductions, Costs & Technical Considerations

Corporate Fleet of Gasoline Vehicles

When the Region estimated the potential benefits associated with a switch to E10 from conventional gasoline, it determined that substantial reductions could be gained, particularly with regard to CO, for a very small one-time cost (*See Table 6*).

Because E10 costs the same as conventional gasoline, the Region concluded that its use would not increase fuel costs. However, because ethanol has a tendency to "clean" fuel lines and deposit small particles on the fuel filter, the Region has anticipated that there will be a one-time cost of $15,000 that will result from the need to incorporate in-line fuel filters into existing pumps before E10 is used, and to replace vehicle fuel filters after its introduction (Waterloo, 2002, p. 26).

Corporate Fleet of Off-Road Diesel Vehicles
When the Region considered replacing off-road diesel used in its off-road Corporate Fleet, it considered three options: 1) Using on-road diesel; 2) Using a B20/on-road diesel blend; and 3) Using ULSD that contains15 ppm sulphur. The Region decided to purchase conventional on-road diesel for it's off-road fleet because this change could produce very significant reductions in emissions (i.e. >9 tonnes/ year) for relatively little cost *(see Table 6)*.

Corporate Fleet of On-Road Diesel Vehicles
When the Region estimated emissions-reduction options for its on-road Corporate Fleet, it considered: 1) Using a B20 biodiesel blend; and 2) Using ULSD. The assessment indicated that ULSD would provide greater reductions in PM and SO_2 while the B20 blend would provide greater reductions in CO and VOCs (*see Table 6*). For the time being, the Region has decided to stay with on-road diesel because of concerns about how ULSD fuel could impact on the fuel economy and performance of heavy-duty diesel vehicles (Bromley, 2003).

Table 6 **Potential Annual Emission Reductions (kg) & Estimated Costs, Various Fuel & Vehicle Options, Region of Waterloo, 2002**

Options for Various Fleets	CO	VOCs	PM_{10}	NOx	SOx	Cost to Implement
Gasoline Fleet: E10	32,908	2,351	149	1,691	65	$15,000
On-road Fleet: B20	398	120	37	+62	63	$82,000
On-road Fleet: ULSD	0	0	114	0	300	$48,000
Off-road Fleet: On-road Diesel	0	0	760	0	8,528	$76,300
Off-road Fleet: B20 / On-road Diesel	1,209	294	985	+401	9,055	$81,000
Off-road Fleet: ULSD	0	0	1,464	0	11,050	$114,000
Buses: ULSD	0	0	1,035	0	2,810	$321,500
Buses: CEM	14,206	2,044	499	1,881	0	$180,000
Buses: CEM & ULSD	14,206	2,044	1,536	1,881	2,810	$180,000 & $321,500

Source: Region of Waterloo, 2002

Buses
When the Region estimated emissions reductions that could be achieved with its transit fleet, it considered four options: 1) Using ULSD; 2) Equipping 86 of 143 buses with catalytic exhaust mufflers (CEM) (i.e. oxidation catalysts); 3) Equipping 86 buses with CEM and using ULSD; and 4) Replacing retiring buses with new models equipped with continuously regenerating diesel particulate filters (CR-DPF).

The assessment indicated that the use of ULSD would produce significant reductions in SOx and PM, while the CEMs would produce significant reductions in CO and VOCs. Combined, the two measures would produce the benefits of both (see Table 6 below).

The Region has decided to: 1) Purchase ULSD for the Region's buses which is expected to cost about $0.035 to $0.04 per litre more than the high grade on-road diesel which would have cost the Region about $0.62 per litre; and 2) Retrofit 86 of the Region's older buses with CEM that cost less than $5,000 each. Staff have also recommended to Council that the Region ensure that newly purchased buses are equipped with CR-DPF at an additional cost of $15,000 per bus (Note: buses cost about $500,000 each) (Bromley, 2003).

Quantities Purchased
The Region purchases about:
- 450,000 litres of diesel for its on-road diesel Corporate fleet,
- 500,000 litres of diesel for its off-road Corporate fleet,
- 1 million litres of gasoline for its Corporate Fleet, and
- 4.2 million litres of diesel for its Transit Authority (Bromley, 2003).

Non-Conventional Fuels Not Selected
Biodiesel was not selected for use by the Region for two reasons: 1) It is expensive relative to on-road diesel (i.e. $0.76 per litre in 2002 compared to $0.61 for conventional on-road diesel); and 2) because B20 is blended with on-road diesel that currently has sulphur levels ranging around 400 ppm, it cannot be used with the new emission control devices that are entering the field. The Region decided that it made sense to select a fuel that is supported by the new legislative and technological developments in this field (i.e. ULSD and CR-DPF comply with the 2007 fuel and vehicle requirements)(Bromley, 2003).

Emissions Credits
While the Region is aware that some of its actions in the area of fuel and vehicles might be eligible for emissions credits, it has not addressed the issue in the Tender. Staff at the Region are working on the emissions trading issues outside of the context of the fuel purchasing tender.

Departments Involved
The Discussion Paper that drove the development of the Region's fuel and vehicle purchasing policies was the product of collaboration between the Region's Public Health, Finance, Corporate Resources, Transportation and Environmental Services, and Planning Housing and Community Services departments, with assistance by Torrie Smith Associates (Region of Waterloo, 2002).

Contact
Rob Bromley, Health Promotion Officer, Regional Municipality of Waterloo, brob@region.waterloo.on.ca.

Case #3: City of Brampton – Fuel Purchasing Practice

Overview & Rationale

In April 2002, the City of Brampton began buying B20 (20% biodiesel; 80% conventional on-road diesel) for use in its Corporate on-road and off-road diesel fleet. This decision was made to reduce emissions of smog-forming air pollutants. The biodiesel, made from virgin soybeans, was purchased from Big K Fuels, who blended it with on-road diesel purchased from Imperial oil.

The City also plans to use B20 in its Transit Authority fleet beginning in the spring of 2003 and to use neat biodiesel (B100) in its Corporate fleet in the summer months in 2003. It also plans to use E10 (10% ethanol; 90% gasoline) in its gasoline-fuelled vehicles to reduce emissions of smog-forming air pollutants and to increase vehicle performance.

The City has implemented this policy by adding an "Alternative Fuels" section to its RFP in which it asks for bids on B100, B50 and B20.

Emissions Reductions Expected

The City moved to a biodiesel blend in 2002 for its diesel vehicles because of the emissions reductions that could be achieved with this fuel without making expensive modifications to vehicles or expensive investments in new infrastructure. The City has not attempted to calculate the emissions reductions associated with its purchase. However, it is expected that the City's purchase will reduce emissions in four ways: 1) By using on-road diesel in its off-road fleet, the City can reduce SO_2 emissions from that portion of its fleet by about 88% (i.e. the average sulphur level in on-road diesel in Ontario is 360 ppm compared to an average of 2,890 ppm in off-road diesel); 2) By blending biodiesel with on-road diesel, the City can reduce SO_2 emissions from the on-road diesel by up to 20%; 3) by using B20, the City expects to reduce emissions of PM, HC and CO from the Corporate diesel fleet; and 4) By using E10, the City expects to reduce smog-forming air pollutants from its gasoline fuelled fleet.

Costs

In 2002, the B20 was costing the City of Brampton about $0.04 more per litre than it would for conventional on-road diesel. However, the price differential may increase to about $0.12 per litre this year (i.e. from about $0.62 per litre for conventional on-road diesel to about $0.74 per litre for B20) because the U.S. government has recently dropped the subsidy provided to its soy-based biodiesel industry. If that subsidy is reinstated, it is expected that prices will drop again (Dack, 2003).

In Ontario, there is a tax break associated with using biodiesel. The $0.143 per litre fuel tax that currently applies to on-road diesel is not charged on neat biodiesel. With a B20 blend, this tax break amounts to about $0.03 per litre. A number of organizations are lobbying the Ontario government to increase the tax break provided to B20 to encourage its use and the industry's development (Dack, 2003). The price of B20 diesel would be reduced if greater volumes were purchased (i.e. if other municipalities pooled their fuel purchases with the City of Brampton).

Quantities Purchased
Each year, the City of Brampton purchases about:

- 480,000 litres of diesel for its on-road and off-road Corporate Fleet;
- 5.2 million litres of diesel for its Transit Authority;
- 554,500 litres of gasoline for its Corporate fleet.

Technical Considerations/Concerns
The City has encountered no technical difficulties with the use of B20 in its entire fleet, even though the weather conditions this winter have been extremely cold. The shift in fuel has required no expensive retrofits of vehicles, pumps or storage facilities. It has not resulted in any increase in maintenance costs. The B20 is delivered by truck from a terminal in Mississauga.

The City will use B100 in its Corporate fleet in the summer months only. B100 can only be used during warm seasons because it becomes viscous (i.e. thick) in cold weather. B100 is also more corrosive than conventional diesel and can produce problems with plastic pipes and gaskets used in older vehicles (Dack, 2003).

Emissions Credits
Ownership of emissions credits created with this purchase have not been addressed in the Tender.

Non-Conventional Fuels Not Selected
Natural gas was considered by the City but was not selected because of the expense of purchasing new equipment and vehicles and because of the infrastructure needed to support this option (Dack, 2003).

Ethanol/diesel blends were not considered because these fuel blends have not been "proven" the way that B20 blends have been (Dack, 2003).

Biodiesel produced from animal products was not selected because the City did not feel that it had been "proven" the way that biodiesel produced from pure soybeans has (Dack, 2003).

Departments Involved
These fuel purchases have been driven by Fleet Services alone.

Contact
Ken Dack, Manager, Fleet Services, City of Brampton, ken.dack@city.brampton.on.ca

IV: Evaluation of Non-Conventional Fuel Options & Low-Sulphur Conventional Fuel Options

For the purposes of this report, non-conventional fuels were considered only if: 1) they have been used by one of the three municipalities examined; 2) they are accessible to the Ontario market; and 3) they do not require expensive modifications of vehicles or infrastructure.

A. For Gasoline Fuelled Vehicles

Two options have been identified for reducing emissions from gasoline-fuelled vehicles between now and January 2005 when the 30 ppm standard will come into effect across the country:

1) Purchasing gasoline from the supplier with the lowest sulphur levels as the City of Toronto has been doing; and
2) Purchasing E10 as the Region of Waterloo and the City of Brampton plan to do.

1. Favouring Gasoline with Lowest Sulphur Levels

For the last four years, the City of Toronto has awarded its gasoline bid to the company with the lowest annual average sulphur level at the refinery. This approach has reduced direct annual emissions of SO_2 from the City's gasoline fleet by approximately 40 to 50% or by about 1 tonne per year. It is also expected to reduce emissions of SO_4, PM, CO, NOx and VOCs from the City's gasoline-fuelled fleet (ASEP, 1997).

If, as Environment Canada expects, most refineries in Ontario will be achieving the 30 ppm sulphur standard for gasoline by the summer of 2003, there is no reason for municipalities to purchase gasoline with sulphur levels greater than 30 ppm after the fall of 2003 (except in the case of extended fuel contracts). If municipalities purchase gasoline that contains 30 ppm sulphur, they will be reducing SO_2 emissions from their gasoline-fuelled fleets by an average of 92% relative to 2001. This would require, however, developing some mechanism for ensuring that suppliers provide gasoline that contains on average 30 ppm sulphur, when sulphur levels are known to fluctuate from one season to the next, and when performance from previous years will no longer be relevant.

2. Purchasing Ethanol Blended Gasoline

The Region of Waterloo and the City of Brampton have elected to purchase E10 (10% ethanol/90% conventional gasoline) for their gasoline fuelled fleets as a means of reducing emissions of smog-forming pollutants from their Corporate fleets.

Ethanol is an alcohol fuel that is commonly made from corn or sugar but can be made from any biological feedstock that contains appreciable amounts of sugar or starch. Ethanol is most commonly blended with gasoline to form an E10 blend or an E85 blend (85% ethanol/15% gasoline). While the higher concentrations must be used in vehicles that have been modified, the lower concentrations (E5-E10) can be used in all types of vehicles and engines that require gasoline. E10 can also be used without expensive modifications in most storage tanks, distribution systems and vehicles in use today (AFDC, 2003).

Ethanol and Carbon Dioxide

Ethanol has been promoted by many sectors because it is a renewable fuel that can reduce CO_2 emissions that contribute to climate change, increase security of fuel supplies, and support local economies. The Canadian Renewable Fuels Association (CRFA) reports that E10 may reduce CO_2 emissions by 6 to10% on a life-cycle basis relative to conventional gasoline (CRFA, 2003). Environment Canada estimates that the reduction in CO_2 emissions on a life-cycle basis are closer to 3 to 4% (Basak, 2003).

Ethanol, Emissions Reductions & Technical Considerations

In the United States, ethanol has been added to gasoline as an "oxygenate" that is suppose to increase the octane of the gasoline, and improve the combustibility of the fuel, so that it burns cleaner. The Canadian Renewable Fuels Association reports that E10 blends can reduce emissions of CO by 25 to 30% and VOCs by 6 to 10% while increasing emissions of aldehydes (air toxics) by 30 to 50% relative to conventional gasoline (CRFA, 2003). Staff at Environment Canada report that E10 does increase emissions of the air toxic, acetaldehyde, while slightly reducing emissions of SO_2 and the air toxic, benzene. They have cautioned however, that it is not clear that ethanol will reduce VOCs and CO when used in Canada. Apparently, ethanol can have varying impacts on emissions of VOCs and CO depending upon the age and model of the vehicle in which it is used and on the properties of the gasoline with which it is blended. Of particular importance in this regard is the vapour pressure requirements applied to gasoline when ethanol is used, which vary from one province to another, and between Canada and the United States. Environment Canada staff have also reported that the emission impacts of E10 are diminishing as more stringent vehicle emissions standards come into effect (McEwen, 2003).

Concerns have been expressed in some quarters about how increased emissions of aldehydes may impact on air quality and human health. One study conducted by the Argonne National Laboratory in the U.S. concluded that E85 significantly reduces the overall toxicity of vehicle emissions because, while it increases emissions of acetaldehyde and formaldehyde, it decreases emissions of benzene and 1,3-butadiene (DOE, 2002, p.50-58)(*see Appendix B for more details*). Environment Canada staff have cautioned that the results of the Argonne study can not be applied to Canada because they are based on U.S. gasoline which has significantly different properties than Canadian gasoline (McEwen, 2003).

Costs, Fuel Economy & Availability

Both the City of Brampton and the Region of Waterloo found that E10 could be purchased in 2003 for the same price as conventional gasoline.

Environment Canada staff have reported however, that there is some loss of fuel economy with E10 blends (i.e. a reduction of about 3%) (McEwen, 2003).

Ethanol-blended gasoline has been subjected to tax breaks from the federal and provincial governments to encourage its development. At present, the federal government waives the federal excise tax on the ethanol portion of gasoline, which reduces the cost of E10 by $0.01 per litre. Ontario exempts ethanol from the province's *Gasoline Tax Act* which amounts to cost reductions worth $0.147 per litre of ethanol or $0.01 per litre of E10 (Basak, 2003).

In the United States, the demand for ethanol has grown since the Clean Air Act Amendments of 1990 mandated the sale of "oxygenated fuels" in areas with unhealthy levels of CO. Today, approximately 1.5 billion gallons of ethanol are added each year to gasoline in the United States to increase octane and improve the emissions quality of gasoline (AFDC, Ethanol, 2003).

In 1998, it was reported that approximately 234 million litres of ethanol were being produced in Canada each year (Env Can, 1998). Under the Climate Change Plan, the federal government has proposed increasing E10 penetration of the gasoline market to 35% by 2010. This would increase ethanol consumption in Canada to 1 billion litres per year (Basak, 2003).

B. For Diesel-Fuelled Vehicles

1. On-Road Diesel for Off-Road Vehicles

While technically one would not call on-road diesel an alternative fuel, it can be used as an alternative to off-road diesel for off-road diesel vehicles. When off-road diesel, that contains on average 2,890 ppm sulphur, is replaced with on-road diesel, that contains on average 360 ppm sulphur, SO_2 emissions can be reduced by about 87.5%. This reduction in sulphur levels will also produce substantial reductions in directly emitted SO_4 and PM and in the secondary formation of SO_4 and PM in the atmosphere (ASEP, 1997).

In Toronto, the use of on-road diesel in the City's off-road fleet has reduced annual SO_2 emissions by about 9 tonnes. While this practice has increased the cost of diesel for the off-road diesel fleet by as much as 5.7% one year, in 2003, it actually reduced the cost by 2.7% (Gingrich, 2003).

2. Conventional On-road Diesel with Lowest Sulphur Levels

Given that sulphur levels in on-road diesel in Ontario ranged from 278 to 437 ppm in 2001, substantial air quality benefits can be gained by simply favouring the supplier with the lowest sulphur levels, as the City of Toronto has done. In 2003, Toronto will reduce its SO_2 emissions by an additional 1.6 tonnes by selecting conventional on-road diesel from the supplier with the lowest sulphur levels.

3. Ultra Low Sulphur Diesel (ULSD)

Ultra Low Sulphur Diesel (ULSD) is the term applied to conventional petroleum-based diesel that contains less than 15 ppm sulphur. While ULSD has not previously been available in Ontario, a few companies are now willing to offer it to Ontario consumers.

Petro Canada has agreed to ship ULSD to the Region of Waterloo from Montreal in 2003, and is upgrading its storage facilities at its Mississauga location so it can service the Ontario market from this location in the future (Bromley, 2003). Shell has also indicated to the Region of Waterloo, a willingness to offer ULSD to Ontario consumers. Shell would be shipping ULSD to Ontario consumers by pipeline, rail and truck from its refinery in Edmonton (Bromley, 2003).

ULSD & Cost

This year, Petro Canada has offered to sell ULSD to the Region of Waterloo for $0.6525 per litre (or for $0.005 per litre above the fluctuating price set by the Oil Buyer's Guide). This price, which includes the product, taxes and shipping, is about $0.03 to 0.04 more per litre than the premium grade on-road diesel the Region was considering (i.e. $0.62 per litre) and $0.04 to 0.05 more per litre than conventional on-road diesel (i.e. $0.61 per litre) (Bromley, 2003).

ULSD & Emissions Reductions

If ULSD is used instead of on-road diesel, which contains on average 360 ppm sulphur, SO_2 emissions from an on-road fleet could be reduced by an average of 96%. If ULSD is used instead of off-road diesel, which contains on average 2,890 ppm sulphur, $S0_2$ emissions from an off-road fleet could be reduced by an average of 99.5%.

When ULSD is used, substantial reductions are also expected in the direct release of SO_4 and PM from vehicles, and in the secondary formation of SO_4 and PM in the atmosphere. More importantly, however, the use of ULSD allows for better performance from some emission control devices and for the use of more advanced emissions control devices, both of which have been designed to reduce a broad array of smog-forming and toxic air pollutants.

While the scope, timing, and resources provided for this project do not allow for the examination of vehicle technologies, emission control devices, and their combined impact on emissions, it is important to understand that fuel choices impact upon the operation and performance of emission control devices that can be retrofitted on older vehicles or installed on new vehicles.

Oxidation Catalysts

Among the emission control devices that can be affected by sulphur emissions are oxidation catalysts. Several studies suggest that oxidation catalysts are capable of producing substantial reductions in emissions of CO, HC, and PM, and slight reductions in NOx emissions, when installed on older models of diesel vehicles that are fuelled with conventional diesel. The U.S. EPA has estimated that catalytic exhaust mufflers (CEMs) (i.e. mufflers equipped with oxidation catalysts) can reduce emissions of PM, CO, and HC by about 40 to 50% and emissions of NOx by about 2.8 to 4.4% when installed on heavy-duty 4-stroke diesel engines (Region of Waterloo, 2002) (*see Table 7*).

Environment Canada has determined that emissions from older buses can be significantly reduced by retrofitting them with oxidation catalysts. In a 1999 report prepared for Environment Canada, it is reported that emissions of PM, HC, CO and NOx were reduced by about 34%, 71%, 74% and 3.8% respectively when buses built in 1984/85 were retrofitted with a CEM. In 1999, the cost to retrofit a bus with a CEM was estimated at about $2,500 to $3,000. In 2001, Environment Canada estimated that the cost would be closer to $3,200 (Env Can, 1999; Burelle, 2003).

Table 7 **% Reduction in Air Emissions, In Heavy Duty Diesel Vehicles with CEM, EPA**

	CO	HC	PM_{10}	NOx
CEM	40- 42	43 - 50	39 - 50	2.8 - 4.4

Source: Region of Waterloo, 2002

Environment Canada has also determined that emissions from older buses that do not have electronic engines (i.e. model years 1986 to 1993) can be reduced by greater percentages when their engines are rebuilt with electronic engine controls and retrofitted with CEMs. In the 1999 study, it was estimated that emissions of PM, HC, CO, and NOx would be reduced by 92%, 71%, 74%, and 33% respectively when the engines were rebuilt with electronic engine controls and retrofitted with CEMs. It was estimated that these changes would cost between $20,000 to $50,000 per bus (Env Can, 1999). It was also estimated that this strategy would reduce both CO_2 emissions and fuel costs by about 8% because it would increase the vehicle's fuel efficiency by about 8% (Env Can, 1999) (*see Table 8*).

ULSD & Oxidation Catalysts
When ULSD is used in diesel-operated vehicles that are equipped with CEMs, a variety of air emissions can be further reduced because the sulphur compounds are no longer interfering with the catalyst's ability to react with the other air emissions

Table 8 **% Reduction in Air Emissions from Older Buses Equipped with CEM or CEM & Electronic Engine Controls, Conventional On-Road Diesel**

	CO	HC	PM_{10}	NOx	CO_2
Retrofit - CEM	74	71	34	3.8	N/R
Retrofit - CEM & Electronic Engine	74	71	92	33	8

(N/R = Not Reported)
Source: Env Canada, 1999

in the exhaust stream. For example, a study conducted on New York City buses indicated that when ULSD (i.e. 30 ppm) was used in buses equipped with CEMs, emissions of CO, PM, and PAHs were reduced by an additional 15 to 35%, while emissions of total hydrocarbons (THC), SO_4 and SO_2 were reduced by an additional 76 to 92%, relative to the same buses fuelled on diesel that contained 250 ppm sulphur (*see Table 9*)(Lanni, 2001)(*See Appendix A*).

ULSD & Diesel Particulate Filters

Continuously regenerating diesel particulate filters (CR-DPF) are an example of an advanced emission control technology that is both, more effective at reducing a broad array of air emissions from diesel-fuelled vehicles, and more sensitive to sulphur emissions. While an oxidation catalyst is less effective when used with conventional on-road diesel, the diesel particulate filter (DPF) can be damaged by the SOx emissions associated conventional on-road diesel.

Table 9 **% Reduction in Air Emissions from Older Buses Equipped with Catalytic Exhaust Mufflers, ULSD Relative to 250 ppm Sulphur Fuel**

	CO	THC	PM_{10}	NOx	CO_2	PAHs	SO_4	SO_2	Carbonyl
ULSD	34.7	66.7	15.0	0	+0.2	15	92	91	10

Source: Lanni, 2001

When buses in New York were retrofitted with CR-DPF, and operated on ULSD, emissions of a number of smog-forming and toxic air pollutants were reduced by 70 to 90% relative to those emissions from buses when they were equipped with CEM and fuelled with conventional on-road diesel (i.e. 250 ppm sulphur)(Lanni, 2001; Chatterjee, 2002)(*See Table 10 below*).

The Region of Waterloo has determined that new buses, which cost about $500,000 each, can be equipped with CR-DPF for about $10,000 to $15,000 each (Bromley, 2003).

Table 10 **% Reduction in Air Emissions of Buses Retrofitted with DPF & Fuelled with ULSD, Relative to Buses with Catalytic Exhaust Mufflers**

	CO	HC	PM_{10}	NOx	CO_2	PAHs	SO_4	SO_2	Carbonyl
ULSD	90	70	90	+3.1	+10	70-80	93	88	90 - 99

3. Biodiesel

Several companies are now offering biodiesel to customers in Ontario. For example, three companies submitted bids to provide biodiesel and biodiesel blends to the City of Brampton; two U.S. companies, NOCO and Big K Fuels, and a Canadian company, Bio-Diesel Canada (Dack, 2003).

Biodiesel fuels can be derived from plant or animal sources. Fats and oils are chemically reacted with an alcohol such as methanol to produce chemical compounds known as fatty acid methyl esters. These esters are called biodiesel when they are intended for use as a fuel (AFDC, 2003).

In the United States, biodiesel is being used by the U.S. Departments of Energy and Agriculture, the U.S. Postal Service and by a large number of school districts, national parks, transit authorities, public utility companies, and garbage and recycling companies (AFDC, 2003). In Ontario, biodiesel is being used for the Corporate Fleets belonging to the City of Brampton, the Town of Caledon and Toronto Hydro (Dack, 2003).

Biodiesel & Technical Considerations

Biodiesel fuels can be added to, or used in place of, conventional petroleum-based diesel fuels. Biodiesel is often mixed with conventional petroleum-based diesel to create blends. When blended in concentrations up to 20%, biodiesel can be used in nearly all diesel equipment and is compatible with most storage and distribution equipment. No engine modifications are needed. The 20% blends are called B20 (AFDC, 2003).

Higher blends, even neat biodiesel (i.e. B100) can be used in many engines built since 1994. Biodiesel is expected to work well with new technologies such as catalysts, particulate traps and exhaust gas recirculation (AFDC, 2003). However, higher blends can present difficulties in cold climates because of viscosity (i.e. tendency to thicken in low temperatures) (OEE, 2003).

Biodiesel Fuel Economy

Biodiesel has a reduced energy content relative to conventional diesel fuels, which translates into a reduction in fuel economy. However, as can be seen in Table 11 below, fuel economy is reduced by only 1.6 to 2.1% with B20 blends (EPA, 2002, p.44).

Biodiesel Costs

B20 was costing the City of Brampton about $0.04 per litre more than conventional diesel in 2002. This year, B20 may cost as much as $0.72 per litre, which is currently $0.12 per litre more than conventional on-road diesel. If the U.S. reinstates its subsidy, the price of biodiesel is expected to drop again.

Biodiesel & Global Climate Change

Since biodiesel is produced from plant oils and animal fats, it has been promoted as a means for reducing emissions of CO_2 that contribute to global climate change. While biodiesel does not appear to reduce CO_2 emissions at the tailpipe, a life-cycle analysis conducted by the U.S. government's National Renewable Energy Laboratory (NREL) suggests that the overall fuel cycle for biodiesel reduces CO_2 emissions by 78.4% relative to conventional diesel fuel. This reduction is attributed to the fact that almost 94% of the carbon emitted from the tailpipe is recycled in the soybeans used to produce it. For B20 blends, the analysis indicates that overall CO_2 emissions are reduced by 15.7% relative to conventional diesel (DOE, 1998).

Table 11 Difference in Energy Content, Biodiesel & Conventional Diesel

Fuel Type	Energy Content (btu/gallon)	% Difference Relative to Conventional Diesel
Conventional Diesel	129,500	
Animal-based Biodiesel (100%)	115,720	-10.6
Animal-based B20 (20% blend)		- 2.1
Plant-based Biodiesel (100%)	119,216	- 7.9
Plant-based B20 (20% blend)		- 1.6

Source: EPA, 2002, p.44

Measures being considered by the federal government to promote the use of biodiesel as a transportation fuel were outlined in the recent October 2002 Climate Change Plan. This plan proposes that federal, provincial and territorial governments collaborate on the policies needed to reach a target of 500 million litres of domestic biodiesel production by 2010 (Basak, 2003).

Biodiesel & Sulphur

A 1998 report prepared by the U.S. National Renewable Energy Laboratory (NREL) reports that neat biodiesel contains no sulphur (DOE, 1998). Therefore, the sulphur levels in biodiesel blends will reflect the sulphur levels in the base fuel with which they have been blended. For example, with a B20 blend, there should be 20% less sulphur than exists in the conventional diesel fuel with which it has been blended.

Biodiesel Impacts on Emissions

A report prepared in 1998 on biodiesel for Environment Canada concluded that, while biodiesel's impact on vehicle emissions varies depending upon the feedstock used for the biodiesel, the base fuel used for blending, the vintage of the vehicle tested, and the testing conditions, generally biodiesel appears to reduce emissions of PM, CO and HC, while increasing slightly the emissions of NOx (Env Can, 1998). The report observes that the emissions reductions gained by combining B20 with an oxidation catalyst are very similar to the emissions reductions gained when combining conventional diesel with an oxidation catalyst (Env Can, 1998).

Biodiesel Impacts on Emissions Buses – 1994

When the NREL compared tailpipe emissions from conventional buses powered with neat biodiesel (B100) and B20 produced from soybeans, to those from buses powered with conventional diesel, it found that B20 reduced emissions of CO, PM_{10}, THC, SOx and CO by 9 to 18%, while increasing emissions of NOx by 1.7% (*see Table 12*). In this analysis, it was assumed that bus engines would be calibrated to meet 1994 vehicle emission standards (DOE, 1998). PM emission standards for urban bus engines were tightened in the U.S. in 1994 (Rideout, 2003).

Biodiesel Impacts on Emissions Heavy-duty On-road Diesel, 1988 -1997

When the EPA conducted an analysis of emissions data available for conventional heavy-duty on-road diesel vehicles fuelled on B20, B100 and conventional diesel, it found that B20 reduced emissions of THC, CO and PM_{10} by 10 to 21% relative to conventional diesel, while slightly increasing emissions of NOx (*see Table 13)*. The average level of sulphur in the conventional diesel used in these vehicles was 333 ppm. Most of the emissions data was available for vehicles grouped into three model categories: 1994 to1997, 1991 to1993, and 1988 to 1990 (EPA, 2002). The emission standards that applied to these three categories of heavy-duty on-road diesel vehicles were significantly different. The NOx standard was reduced significantly in 1990 and 1991, while the PM standard was reduced significantly in 1991 and 1994 (Rideout, 2003).

Table 12 **% Change in Emissions in Conventional Buses, 1994 Model Year, B20 & B100 Relative to Conventional Diesel (500 ppm sulphur)**

Fuel	CO	THC	PM_{10}	NOx	SOx
B20	- 9.0	- 9.25	- 13.6	+ 1.7	- 17.6
B100	- 46	- 37	- 68	+ 9	- 100

Source: DOE, 1998, P. 22

It also found that biodiesel's impact on emissions varies depending on three factors: 1) The source of the biodiesel; 2) The engines in which they were used (i.e. model years); and 3) The properties of the diesel

Table 13 **Estimated % Change in Emissions from Heavy-Duty On-Road Diesel Vehicles, B20 & B100 Relative to Conventional Diesel**

Fuel	CO	THC	PM_{10}	NOx	SOx
B20	- 11.1	- 21.1	- 10.1	+ 2.0	N/R
B100	- 47	- 67	- 47	+ 10	N/R

(N/R : Not Reported)

Source: EPA 2002

fuel with which the biodiesel was blended (EPA, 2002)(*see Appendix A for more details*).

Biodiesel Impacts on Air Toxics
The EPA staff also compared the impact of biodiesel on air toxics emitted from the tailpipes of heavy-duty on-road engines. Emissions data were available for 11 of the 21 air pollutants formerly identified by the EPA as Mobile Source Air Toxics (MSAT). When the measurements for the 11 air toxics were considered as a whole, and correlated against the biodiesel concentration, it was found that total gaseous air toxics were reduced when biodiesel was added to conventional diesel fuel, although not to the same extent that total hydrocarbons were reduced. For example, while a B20 blend could reduce total hydrocarbon emissions (THC) by about 20%, it would only reduce total toxics by about 3% (EPA, 2002)(see Appendix A for more details).

Biodiesel Impacts on Emissions Light-Duty Trucks
While biodiesel blends appear to have a significant impact on emissions from conventional diesel vehicles that are not equipped with oxidation catalysts, they appear to have a relatively minor impact on the emissions from diesel vehicles that are equipped with oxidation catalysts. A study was conducted on emissions from light-duty diesel trucks equipped with catalytic converters under four scenarios: 1) using conventional on-road diesel (i.e. less than 500 ppm sulphur); 2) using B10 (10% biodiesel); 3) using B20; and 4) using B30 (30% biodiesel).

The emission rates for HC and CO were very low for all four fuel types, which was attributed to the presence of the catalytic converter. The biodiesel appeared to further reduce emissions of CO and THC and to lower the mass of $PM_{2.5}$, but it did not affect emissions of NOx, total particulate matter, or the mass of non-methane hydrocarbons. This study suggests that the oxidation catalyst lowered the tailpipe emissions from all four fuel types and minimized the compositional differences between the emissions from the different fuel combinations (Rideout,1998).

V: Summary and Recommendations

A. Reducing Emissions from the Gasoline Fleet

Among the three municipalities, two strategies were employed for reducing emissions from their gasoline-fuelled fleets:

1. Favouring bids for gasoline with the lowest sulphur levels; or
2. Purchasing 10% ethanol-blended gasoline instead of conventional gasoline.

1. Favouring Gasoline with Lowest Sulphur Levels.

- With sulphur levels in gasoline coming down to 30 ppm in most refineries in Ontario in the fall of 2003, there is no reason why any municipality should buy gasoline with sulphur levels greater then 30 ppm after that date.
- Gasoline that contains 30 ppm sulphur would be expected to reduce SO_2 emissions from municipal gasoline-fuelled fleets by, on average, 92% relative to 2001.
- Gasoline with 30 ppm sulphur can also be expected to reduce emissions of SO_4, PM, CO, VOCs and NOx.

2. Purchasing E10 (10% Ethanol/90% Gasoline)

- Environment Canada reports that E10 reduces CO_2 by 3-4% on a life-cycle basis.
- Environment Canada reports that there are considerable uncertainties about the air quality benefits associated with ethanol's use in Canadian gasoline.
- Environment Canada reports that ethanol's impact on emissions of HC and CO will vary with the age and model of the vehicle it is used in, and with the properties of the gasoline with which it is blended.
- E10 can be expected however, to slightly reduce emissions of SO_2 and the air toxic, benzene, and to substantially increase emissions of the air toxic acetaldehyde.
- E10 costs no more per litre than conventional gasoline because of tax incentives provided by both the federal and provincial governments, but it does slightly reduce fuel efficiency.

B. Reducing Emissions from the Off-Road Diesel Fleet

There is no doubt that, from a fuels perspective, the biggest emissions reductions can be achieved by shifting away from the use of off-road diesel in a municipality's off-road diesel fleet. With off-road diesel fleets, the options considered by one or more of the three municipalities examined include shifting from off-road diesel fuel that contains 1,200 to 3,700 ppm sulphur to:

1. Conventional on-road diesel that contains 278 to 440 ppm sulphur;
2. ULSD that contains 15 ppm sulphur; or
3. B20 that will contain between 222 to 352 ppm sulphur (i.e. 20% less than the sulphur level in the on-road diesel with which it is blended).

1. Using On-Road Diesel in the Off-Road fleet

- The conventional on-road diesel option can reduce SO_2 emissions from a municipality's total Corporate fleet by as much as 90%.
- The fuel must be dyed red in order to be eligible for the provincial tax breaks of $0.143 per litre that apply to off-road diesel.
- The cost per litre can be 2.7% less to 5.7% more than the cost paid for off-road diesel fuel.

2. Ultra Low Sulphur Diesel (ULSD) in the Off-Road Fleet

- This option has the advantage of further reducing emissions of SO_2, SO_4, and PM, but also increases the price.

3. Biodiesel in the Off-Road Fleet

- Biodiesel is a renewable fuel that can produce climate change benefits.
- When blended with on-road diesel, it can produce greater SO_2 emission reductions than the on-road diesel option, but less than the ULSD option.
- It can also reduce emissions of CO and PM but these reductions are more pronounced in vehicles built before 1994.
- B20 can however, slightly increase emissions of NOx and slightly reduce fuel economy.
- B20 also appears to present some uncertainties respecting price.

C. Reducing Emissions from On-Road Diesel Fleet

With on-road diesel fleets, the options considered by one or more of the three municipalities examined include:

1. Selecting the conventional on-road Diesel with the lowest sulphur levels;
2. Retrofitting buses with catalytic exhaust mufflers (CEM);
3. Using ULSD in buses and/or the Corporate fleet;
4. Using ULSD & retrofitting buses with CEMs;
5. Using B20 in buses and/or in the Corporate fleet; and
6. Using B100 biodiesel in the Corporate fleet in summer months.

1. Conventional On-Road Diesel with Lowest Sulphur Levels

- By indicating in the Tender that sulphur levels will be considered as well as cost, municipalities can choose to select the conventional on-road diesel that has the lowest sulphur levels.
- This option can reduce emissions from the on-road fleet by up to 37% and can be cost neutral.

2. Retrofits for Older Buses

- The installation of catalytic exhaust mufflers (CEMs) on heavy-duty on-road diesel vehicles for which CEMs are not standard equipment, can reduce emissions of CO, PM_{10} and NOx by up to 40%, 44% and 3.3% respectively.
- The installation of CEMs on older buses can reduce emissions of PM, CO and NOx by up to 34%, 74% and 3.8% respectively for a cost of about $3,200 per bus.

- The rebuilding of older bus engines with electronic engine controls and installation of CEMs can reduce emissions of PM, CO and NOx by up to 92%, 74% and 33% respectively (i.e. model years 1986 to 1993) for a cost of $20,000 to $50,000 per bus.
- This latter approach can also reduce fuel costs and CO_2 emissions by about 8% as well by increasing the vehicle's fuel efficiency by about 8%.

3. Ultra Low Sulphur Diesel (ULSD) in On-Road Diesel Fleet

- ULSD can reduce SO_2 emissions by about 95% when used in on-road vehicles (i.e. from an average of 360 ppm to 15 ppm); it will also reduce emissions of SO_4 and PM.
- ULSD will cost the Region of Waterloo about 6.5% more than conventional on-road diesel in 2003.

4. ULSD & Retrofits

- ULSD can also significantly improve the performance of oxidation catalysts so that emissions of smog-forming air pollutants such as CO and PM, and air toxics such as PAHs, are reduced by up to 35%,15% and 15% respectively, relative to buses run on conventional on-road diesel
- ULSD use is essential to the use of more advanced emission control technologies such as continuously regenerating diesel particulate filters (CR-DPF) that can reduce emissions of CO, PM and PAHs by up to 90%, 90% and 80% respectively, relative to buses with CEMs and conventional on-road diesel.
- A new bus, costing about $500,000, can be equipped with CR-DPF for about $15,000.
- The ULSD and retrofit options have the advantage of moving a municipality towards fuels and vehicle technologies that will be required for compliance with vehicle emission standards coming into effect between 2007 and 2010.

5. B20 Biodiesel Blend

- B20 can reduce CO_2 emissions by about 16% on a life-cycle basis relative to conventional diesel.
- B20 can reduce emissions of CO and PM by up to 11% and 10% respectively, although these reductions vary depending upon the age and model of the vehicle, the source of the biodiesel, and the properties of the diesel with which it is blended.
- B20 can also reduce SO_2 emissions by up to 20%.
- On the other hand, B20 can increase emissions of NOx by about 2% and decrease fuel economy by about 2%.
- B20 has the disadvantage of widely fluctuating prices; in 2002, it cost the City of Brampton about 6.5% more than conventional diesel, but in 2003, it could cost 20% more.

6. Neat Biodiesel (B100)

- B100 can reduce CO2 emissions by about 74% on a life-cycle basis, relative to conventional diesel.
- It has the potential to reduce PM, CO, HC and SOx emissions by 35 to 100%.
- On the other hand, B100 can increase emissions of NOx by about 10%, and can reduce fuel economy by between 8 and 10%.
- B100 cannot be used in cold weather because of its viscosity (i.e. tendency to thicken).
- B100 has the disadvantage of being extremely expensive at present.

D. Recommendations

It is recommended that every municipal partner associated with the GTA Clean Air Council:

1. Commit to purchasing: a) on-road diesel, or b) B20 blended with on-road diesel, for use in their Corporate fleet of off-road vehicles during the next fuel tendering cycle;

2. Commit to purchasing: a) 30 ppm sulphur gasoline, or b) E10 blended with 30 ppm sulphur gasoline, in the next fuel tendering cycle; and

3. Commit to examining the emissions reductions and costs associated with purchasing: a) ULSD, and b) B20, for use in their Corporate fleet of on-road diesel vehicles.

It is recommended that the GTA Clean Air Council:

1. Commit to analyzing the financial costs and emissions benefits associated with retrofitting older buses belonging to the partners of the GTA Clean Air Council with catalytic exhaust mufflers and/or electronic engine controls, and using ULSD as a fuel;

2. Develop a strategy to address the ownership of emissions trading credits created as a result of fuel purchasing policies;

3. Explore the benefits of, and mechanisms available for, pooling the fuel purchases of partners of the GTA Clean Air Council;

4. Establish and coordinate a Green Fleets Subcommittee that monitors legislative, technological and research advancements related to fuels, vehicles and emissions control technologies; shares information; collaborates on projects; and makes recommendations to the GTA-Clean Air Council;

5. Encourage the Ontario Ministry of the Environment, Environment Canada and Transport Canada to support the Green Fleets Subcommittee with expertise and resources; and

6. Distribute this report to other municipalities in Ontario through the Association of Municipalities of Ontario (AMO).

Appendix A: Biodiesel

Biodiesel: Heavy-Duty On-Road Engines: EPA Study: 2002

When the EPA conducted a comprehensive analysis of the impacts of biodiesel on tailpipe emissions from conventional on-road diesel engines (i.e. with no NOx absorbers, PM traps, or exhaust gas recirculation) relative to those associated with conventional diesel (i.e. 333 ppm sulphur), it found that B20 reduces emissions of HC, CO and particulate matter by 10 to 21.1%, while increasing emissions of NOx by 2% (*See Table A1 below*)(EPA, 2002).

Table A1 Estimated Change in Emissions, Heavy-Duty On-Road Diesel Vehicles, B20 & B100 Relative to Conventional Diesel (CD)

Emissions	% Change with B20	% Change with B100
CO	- 11	- 47
HC	- 21	- 67
Particulate Matter	- 10	- 47
SOx	N/R	N/R
NOx	+ 2	+10

(N/R: Not Reported)

Source: EPA, 2002

The EPA found that biodiesel's impact on emissions varies depending on three factors:

1. The source of the biodiesel. Increases in NOx emissions were greater with the plant-based biodiesel fuels than with the animal-based biodiesel fuels, while decreases in PM and CO were greater with the animal-based biodiesel fuels than with the plant-based biodiesel fuels;
2. The engines in which they were used (i.e. model years). The study found that the PM emissions reductions were greater for the 1991-1993 engines than for all engine groups combined; and
3. The properties of the diesel fuel with which the biodiesel is blended. When biodiesel fuels were combined with diesel fuels defined as "clean", NOx emissions increased, and the reductions in emissions of PM, CO, and HC were decreased, relative to those blended with "average" base fuels. The base fuels defined as "clean" had lower levels of aromatics, higher cetane levels, lower density, and lower distillation points than the base fuels defined as "average". The EPA has identified the influence of base fuels on emissions as an area requiring more research (EPA, 2002).

Biodiesel Fuels Examined
The analysis was conducted for biodiesel fuels produced from soybean, rapeseed, canola oils, tallow, grease and lard, although most of the data (about 80%) applied to biodiesel produced from plant esters. The biodiesel fuels were grouped into three categories: soybean, rapeseed/canola, and all animal-based sources esters (EPA, 2002).

Coefficients for basic emission correlations (i.e. those that do not consider the source of the biodiesel fuel, the model of engine, or the base fuel) are listed in Table A2 below.

Table A2

Coefficients for Basic Emission Correlations

	Coefficient
NOx	+0.0009794
Particulate Matter	-0.006384
CO	-0.006561
HC	-0.011195

Source: EPA, 2002

Biodiesel Impacts on Heavy Duty Off-Road Vehicles and Light-Duty Vehicles

While the EPA staff expect biodiesel fuels to impact on emissions from heavy-duty off-road vehicles in a manner similar to that seen with heavy-duty on-road vehicles, they reported that there was insufficient data for off-road engines with which to substantiate this expectation (EPA, 2002).

EPA staff were unable to draw any conclusions about biodiesel's impact on emissions from light-duty on-road and off-road engines because there was insufficient data on emissions for these types of engines (EPA, 2002, p.83).

Biodiesel Impacts on Gaseous Air Toxics

The EPA staff also compared the impact of biodiesel on air toxics emitted from the tailpipes of heavy-duty on-road engines. Emissions data were available for 11 of the 21 air pollutants formerly identified by the EPA as Mobile Source Air Toxics (MSAT).

The 10 MSAT for which emissions data were not available included six metals, dioxin/furans, polycyclic organic material (POM), diesel particulate matter & diesel exhaust organic gases (DPM & DEOG), and MTBE (EPA, 2002).

The 11 air toxics included in the analysis are all gaseous air toxics. When the measurements for the 11 air toxics were considered as a whole, and correlated against the biodiesel concentration, it was found that total gaseous air toxics are reduced when biodiesel is added to conventional diesel fuel, although not to the same extent that HC are reduced. For example, while a B20 blend could reduce total hydrocarbon emissions by about 20%, it would only reduce total toxics by about 3% (EPA, 2002).

When the 11 air toxics were considered individually, the analysis suggested that emissions of acetaldehyde, ethylbenzene, formaldehyde, naphthalene and xylene decrease with increasing concentrations of biodiesel in the fuel blend (EPA, 2002). There was insufficient data to determine how biodiesel concentrations impact on air emissions of acrolein, n-Hexane, styrene, benzene, 1,3-butadiene and toluene (EPA, 2002).

Appendix B: Ethanol

Ethanol: U.S. DOE Assessment of Air Emissions: 1996

Emissions testing was conducted on 21 variable-fuel E85 1992 and 1993 Chevrolet Lumina sedans using a 50% ethanol blend (E50), an 80% ethanol blend (E85), and gasoline that meets the California Phase 2 Reformulated Gas (RFG) requirements.

The results suggested that E85 produces substantial reductions in the emissions of CO, HC, NOx, benzene and 1,3-butadiene, slight reductions in emissions of CO_2, substantial increases in formaldehyde, and 20 fold increases in emissions of acetaldehyde (*see Table B1*). The fuel economy of E85 appeared to be equivalent to that provided by the Phase 2 RFG (DOE, 1996).

Table B1 **% Change in Tailpipe Emissions for Vehicles Operated on E85 Relative to Phase 2 Reformulated Gasoline (RFG)**

Air Emissions	% Change with E85
CO	- 12 to 24
Non-methane HC	- 20 to 22
NOx	- 25 to 32
Carbon Dioxide	Slight Reduction
Benzene	- 79
Formaldehyde	+ 20
Acetaldehyde	+1949
1,3-Butadiene	- 80

Source: DOE, 1996

Ethanol: DOE Assessment of Air Toxics: 2002

The EPA estimates that 60% of total benzene emissions, 56% of 1,3-butadiene emissions, 39% of acetaldehyde emissions, and 33% of formaldehyde emissions in the United States are from mobile sources (DOE, 2000, p.5). When the Argonne National Laboratory compared several conventional and non-conventional fuel types and vehicles for their release of these four air toxics, they found that the use of E85 significantly reduces emissions of benzene, 1,3-butadiene, and combined toxics relative to U.S. conventional gasoline, while significantly increasing emissions of formaldehyde and acetaldehyde (*see Table B2*) (DOE, 2002, p.50-58).

Table B2 **Changes in Toxic Air Emissions with Alcohol Fuel During Operation of Light-Duty Gasoline Vehicle, Relative to Conventional Gasoline**

Air Emissions	85% Ethanol Blend
Benzene	- 85
1,3-Butadiene	- 70
Formaldehyde	+ 230
Acetaldehyde	+1431
Combined Toxics	- 50

Source: DOE, 2002

These tests were directed at light-duty gasoline vehicles. The gasoline defined as "conventional" in this study contained 0.4% (wt) oxygenate (MTBE), 339 ppm of sulphur, 1.5% benzene, and 32% aromatics (DOE, 2000, p.40). Note that Canadian gasoline typically has significantly different properties that U.S. Gasoline (e.g. no MTBE, less than half the benzene [0.6% average], 25 ppm sulphur post 2004.)

When the emissions for the four air toxics were translated into benzene-equivalent emissions using the EPA Cancer Unit Risk Estimates (CURE), it was concluded that E85 could reduce the overall toxicity of vehicle emissions by about 50% relative to a vehicle operated with conventional gasoline (*see Table B3*)(DOE, 2000).

This conclusion reflects the fact that 1,3-butadiene emissions, that are significantly reduced when E85 is used in vehicles, are about 100 times more toxic than acetaldehyde emissions, and about 10 to 30 times more toxic than emissions of formaldehyde, both of which are significantly increased when E85 is used (DOE, 2000, p.60).

Table B3 **EPA Cancer Unit Risk Estimates for Toxic Air Emissions**

Air Emissions	EPA Cure
Benzene	8.3×10^{-6}
1,3-Butadiene	2.8×10^{-4}
Formaldehyde	1.3×10^{-5}
Acetaldehyde	2.2×10^{-6}

Source: DOE, 2002, p. 60

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Ontario Public Health Association
468 Queen St. East, Suite 202
Toronto, Ontario M5A 1T7
www.opha.on.ca
tel: (416) 367-3313 / 1-800-267-6817 (Ont.)
fax: (416) 367-2844
e-mail: **info@opha.on.ca**