AN IMPLEMENTATION STRATEGY TO ENABLE THE CITY OF OTTAWA TO COST EFFECTIVELY REDUCE EMISSIONS FROM ITS VEHICLE FLEET

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Developed For The City Of Ottawa By LOGTECH
EXECUTIVE SUMMARY

Nitrogen oxides, volatile organic compounds, sulphur oxides, carbon monoxide, fine particulate matter and other toxic or potentially toxic substances are produced by vehicle engines and they pollute the air. Carbon dioxide (CO₂), a green house gas and major contributor to Global Warming is also produced.

For 2002, the City of Ottawa’s gasoline and diesel fleets will produce 120,000 tons of CO₂. The bus fleet’s portion of this will be 92,000 tons. During the years since these vehicles were manufactured, the emission level standards for gasoline and on-road diesel engines have been reduced. The older vehicles therefore pollute at a greater rate than the new ones. This situation is uncomfortable to “good corporate citizens”.

These emissions are primarily a function of the technology utilized in a specific engine and the properties of the fuel used. Relative to their gasoline and diesel counterparts, hybrid, CNG and propane fuelled vehicles reduce emissions. Blends of biodiesel and ethanol-diesel reduce emissions in proportion to the percentage of biodiesel and ethanol in the base diesel fuel.

The aim of this paper is to develop the most cost-effective fleet emissions reduction strategy for the City of Ottawa.

Fuel cell vehicles using hydrogen as their fuel are the acknowledged “way ahead”. They will be virtually zero emission vehicles, depending on the source of hydrogen. No infrastructure exists to deliver the hydrogen to useful locations.

Hybrid diesel electric buses are in limited use in the United States. Initial trials have shown positive results and follow-on buys are being made. Hybrid diesel electric buses have the great advantage of requiring no modifications to existing infrastructure and no new infrastructure. When compared to conventional diesel, hybrid diesel electric vehicles have the potential to lower GHG emissions by approximately 25%. This translates into a reduction of 23,000 tons relative to 2002 projected City of Ottawa fleet operations.

CNG as a fuel for urban buses and a good cross section of other vehicles has been the subject of many evaluations. In the United States it is the alternative transportation fuel of choice for buses and light vehicles. In Ontario, the natural gas distribution system is widespread, but only as a source of heating fuel, not vehicle fuel. Refuelling infrastructure is costly and requires a long-term commitment. GHG reduction is similar to that of hybrid diesel electric vehicles.
Only ethanol-diesel and biodiesel blends can be used without costly modifications or additions to existing infrastructure or modifications to engines. Emission reductions are only in proportion to the blend level and cannot be compared to those resulting from a total fuel replacement. The commercial availability of biodiesel is limited. E-diesel is not yet commercially available.

The long-term implementation strategy for the City of Ottawa should be the utilization of fuel cell vehicles. The mid-term implementation strategy should be the utilization of hybrid diesel electric buses.

For the near term, the City should continue to give its full support to the ethanol-diesel test that is currently under way. The Montreal biodiesel project should be monitored to determine if CO₂ reductions warrant further investigation. The cost benefit of new generation particulate traps and oxidation catalysts should be investigated for possible inclusion in new buses and retrofit of old buses.
1.0 BACKGROUND

1.1 The transportation system is the largest user of energy in Canada. In 1999 it consumed thirty five percent of the energy produced. (Transport Canada, 2000, Ch 5, p. 1).

Figure 1 – Canadian Energy Use –1999

1.2 Concomitantly, transportation was and is the single largest producer of manmade greenhouse gases (GHG) in Canada. The largest component (about two thirds of the manmade component) of GHG is carbon dioxide (CO₂) (Transport Canada 2000 Ch 5, p. 1). In 1998 the GHGs from transportation use were in the order of the equivalent of 157 megatons of CO₂.

Figure 2 – Contribution Of Various Sources to Anthropogenic GHG Emissions – 1998
1.3 Vehicle engines produce nitrogen oxides (NOx), volatile organic compounds, sulphur oxides, carbon monoxide (CO), carbon dioxide (CO₂), fine particulate matter (PM) and other toxic or potentially toxic substances. These emissions reduce air quality, particularly in urban areas, as pollution from vehicles is concentrated at ground level and in densely populated areas. A large percent of the population is forced to breath vehicle exhaust directly before it has a chance to mix with cleaner air or degrade into less hazardous by-products. Many have health problems directly attributable to the effects of pollution on their cardiovascular and respiratory systems. In addition to the human suffering, there is a monitory cost to every Canadian due to the added burden on the health system from increased emergency room visits, to hospital care to the costs of prolonged care. These emissions are major contributors to greenhouse gases (GHGs). The GHGs accumulate in the troposphere (the lowest layer of the atmosphere) where they trap the heat reflected from the surface of the Earth. This process elevates global temperatures, which in turn changes the Earth’s climate.

1.4 These emissions are primarily a function of the technology utilized in a specific engine and the properties of the fuel used. Particulate emissions from diesel engines are formed due to the incomplete combustion of the fuel. The formation of NOx is a result of the air-fuel ratio and the temperature of combustion. High temperatures in diesel engines that result from igniting the fuel through compression (as opposed to the Otto cycle) increase NOx formation. Lowering engine temperature decreases NOx levels but tends to increase the amount of fuel which is not combusted and is emitted in the form of PM and HCs. Basically, newer vehicles emit fewer emissions than older ones. Similarly, relative to their gasoline and diesel counterparts, CNG and propane fuelled vehicles tend to reduce emissions and biodiesel and E-diesel fuelled vehicles tend to reduce emissions.

1.5 OC Transpo operates 898 active diesel buses, ranging up to 28 years of age. A great proportion of these will be in service for years to come. There are approximately another 2000 vehicles in the city inventory that run on diesel and gasoline (see Annex A for distribution). During the years since their production, technology has changed, as has the emission standards for gasoline and on-road diesel engines (see table 1). By the year 2004, the new US Environmental Protection Act (EPA) Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements will be in effect. Canada has agreed to harmonize US – Canada emission standards, hence these standards will apply to the production of any new vehicles for the Canadian market (Canadian Gazette, 2001, p 453). However, the older buses and other vehicles remaining in service will continue to pollute at much higher rates. This situation is uncomfortable to “good corporate citizens’. The EPA urban bus diesel emission standards are summarized in the following table:
Table 1- Emission Standards for Urban Bus Diesel Engines, g/bhp-hr

1.6 **GHG Emission Calculations.** To calculate CO₂ emissions from the combustion of various fuels, the Natural Resources Canada Champagne Vehicle GHG Accounting Model was used. The amount of CO₂ released is found by multiplying the estimated annual fuel consumption for each by an emissions factor based on fuel type. Specific fuel type emission factors are provided in the following table:

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Kg of CO₂ per liter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>2.34</td>
</tr>
<tr>
<td>Diesel</td>
<td>2.69</td>
</tr>
<tr>
<td>CNG</td>
<td>2.01</td>
</tr>
<tr>
<td>Propane</td>
<td>2.13</td>
</tr>
<tr>
<td>M100/E100</td>
<td>2.29</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Kg of CO₂ per liter</th>
</tr>
</thead>
<tbody>
<tr>
<td>M85</td>
<td>2.30</td>
</tr>
<tr>
<td>M65/E65</td>
<td>2.31</td>
</tr>
<tr>
<td>E10</td>
<td>2.33</td>
</tr>
<tr>
<td>E7</td>
<td>2.33</td>
</tr>
<tr>
<td>E5</td>
<td>2.34</td>
</tr>
</tbody>
</table>

Table 2 – Kilograms Of CO₂ Per Liter Of Fuel

The production of greenhouse gases is strictly a function of the quantity of fuel burned. For example, if a gasoline vehicle burned 2,000 liters of gasoline annually, the amount of CO₂ produced will be 4,680 kilograms. This table shows that one liter of diesel produces 18 percent more CO₂ than one liter of gasoline, but it must be remembered that a vehicle will travel 30 percent further on a liter of diesel than a liter of gasoline. Hence from the fuel-efficiency point of view, a diesel engine will produce less CO₂ than a gasoline engine. According to the Transportation and Climate Change: Options for Action paper (p. 12), the 1997 transportation GHG emissions per capita in Ontario was 4.32 tons. Based on the City of Ottawa’s population of approximately 700,000, this results in the production of 3,042,000 tons of GHG.
1.7 Next year the City of Ottawa has budgeted for 42,250,000 liters of diesel and 2,750,000 liters of gasoline for fleet use. This will result in the production of over 120,000 tons of CO$_2$. The diesel fleet will produce the vast majority of this, some 114,000 tons or 95%. The bus fleet will produce 92,000 tons of CO$_2$.

![Fleet CO2 Production for 2002](image)

Figure 3 – City Of Ottawa Projected CO$_2$ Fleet Production For 2002
2.0 AIM

2.1 The aim of this paper is to develop for the City of Ottawa the most cost-effective emissions reduction strategy for its vehicle fleet. Additionally, recommendations are to be made regarding the pursuit of technology and fuels for future vehicle procurement.
3.0 APPROACH

3.1 Fuels and technology change quickly and it is often unclear what is available today and what will be available in the foreseeable future. The technologies most often cited include diesel, natural gas, hybrid electric and fuel cell. The fuels include diesel, compressed natural gas (CNG), propane (LPG), gasoline, biodiesel, ethanol and e-diesel. Biodiesel, diesel and ethanol can be used in blends, thus complicating the discussion but facilitating more solutions.

3.2 This paper will examine the factors that must be considered in the selection of a suitable approach to meet the objectives of the program. It includes information regarding and a discussion on alternative fuels and alternative vehicle technology. It will analyze the pollutants by type of fuel and outline the costs and benefits of various technologies in reducing emissions.

3.3 Relative to the world level production of air pollutants and GHGs, the contribution from the City of Ottawa’s vehicle fleet may seem miniscule. However, it will be the cumulative effect of thousands or perhaps even hundreds of thousands of such efforts that will have a significant effect in reducing pollution and stabilizing the world’s climate.

3.4 Even within the City there are many other facets involved in this quest – reducing buildings from buildings, increasing rider ship on OC Transpo and reducing the number of cars with one only one occupant, etc. As stated, the aim of this paper centres on emission reductions from the City’s vehicle fleet – the purview of the Fleet Services Branch. Hence the ameliorating strategies only apply to the effort addressing the vehicle fleet.

3.5 As can be seen from the charts and figures in paragraph 1.7, by a large margin, diesel is the major fuel consumed and buses consume the greatest quantity of this. This paper will, therefore, concentrate on emission reductions from the diesel bus fleet.

3.6 This paper has been circulated to the Green Committee for comment. Replies from Mr Pat McNally and Ms Elaine Gibson have, in the main, been incorporated into the paper.
4.0 CURRENT UNDERTAKINGS

General

4.1 The City of Ottawa has a long history of involvement in projects and action aimed at reducing emissions from the vehicle fleet. The former municipalities made various in-roads to make the fleet more fuel-efficient and to make use of less polluting fuels.

Fuels

4.2 Propane. The City has operated a number of vehicles on propane or liquefied petroleum gas (LPG) since the 1980’s. The City has one LPG refueling site at 951 Clyde Avenue that is integrated into the City fuelling system. The number of vehicles using propane has remained fairly constant in the past 15 years; currently there are 58 in the fleet (see Annex A).

4.3 Natural Gas. CNG has been trialled in a variety of City vehicles ranging from light duty trucks to transit buses. Today it is used mainly in vehicles that operate in enclosed spaces such as ice resurfacers, forklifts and building maintenance machines.

4.4 Electricity. The City’s fleet of electric vehicles consists of warehouse operations-type vehicles such as forklifts, sweepers and utility carts. There is a fairly long history of City involvement in electric vehicles including the development of an electric police motorcycle in the 1970’s that is on display at the Swansea Municipal garage.

4.5 Ethanol blend gasoline. For the past several years the City has used ethanol blended gasoline at one of its City refueling sites. The cost of the fuel is about $0.02/L greater than regular unleaded and is available for use to all City gasoline powered vehicles. The fuel is dispensed at the Swansea location. In 2001, 100,000 litres were used.

4.6 Diesel. The bulk of the City fleet operates on diesel fuel. The City currently purchases a low-sulphur diesel fuel with a maximum of 500 ppm sulphur content. Most engines being purchased today are compliant with 2004 emissions standards.
Diesel Engine Retrofits

4.7 Particulate Traps. The city bus fleet has an extensive history of involvement in projects related to the treatment of diesel exhaust gases to improve the quality of the emission. Particulate traps designed to prevent unburned hydrocarbons from entering the atmosphere were first trialled in 1991. Early particulate traps were prone to soot build up and deemed unacceptable. A new second-generation trap is being installed for further trials.

4.8 Catalytic Converters. The first trials of catalytic converters started in 1994. They have been included on City diesel engines since 1997. Currently 334 buses are equipped with catalytic converters.

Previous CNG Bus And Truck Trials

4.9 The City has conducted trials on various truck and bus configurations using CNG as a fuel. To date the City has not acquired any significant number of CNG vehicles due mainly to the reduced range and payload of CNG vehicles and a limited refueling infrastructure. There has also been limited support for this type of vehicle by the local dealer network.

Drive Clean

4.10 Since 1999 all City heavy-duty diesel vehicles have been required to undergo annual emissions testing as part of the Ontario Drive Clean program. Starting in July 2002, this program will be extended to all City licensed vehicles. This program ensures that vehicles meet minimum emission standards throughout the life of the vehicle. The City operates a number of Provincially Accredited test sites for this program.
5.0 FUELS

Fuel Consumption Factors

5.1 To accurately compare the consumption of different fuels a common frame of reference must be used. The basis for this comparison is the selected energy content (higher heating value) of the fuel, often described as gasoline liter equivalents (GLE). The factors used in this paper are summarized in the following:

<table>
<thead>
<tr>
<th>Fuel Type</th>
<th>Equivalent to 1 liter of Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.36 liter of propane</td>
<td>1.00</td>
</tr>
<tr>
<td>1.39 liter of E85</td>
<td>1.00</td>
</tr>
<tr>
<td>1.76 liter of M85</td>
<td>1.00</td>
</tr>
<tr>
<td>0.8 liter of diesel</td>
<td>1.00</td>
</tr>
<tr>
<td>0.66 kg of CNG</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Table 3 – Fuel Energy Content

5.2 Two other methods of comparing fuels are the distance a vehicle can travel on a given volume of fuel, or the volume of fuel required to give the same energy content as a given quantity of gasoline. These concepts are illustrated in the following tables;

![Vehicle Range On different Fuels (Constant Volume) diagram](image)

Figure 4 – Vehicle Range On different Fuels (Constant Volume)
Full Fuel Cycle

5.3 This is a concept that embraces the “cradle to grave” approach in accounting for the CO₂ emissions generated in the production and consumption of fuel. As an example, for gasoline and diesel fuel it accounts for the energy used and the emissions that result from the drilling, transportation, refining and finally consumption in a vehicle. In the case of ethanol, it accounts for the fertilizer used in the growing of the feedstock and the “credits” resulting from usable byproducts. Another example of this concept is the production of electrical energy in Quebec versus that produced in Ontario. Most electricity produced in Quebec originates in James Bay. Hydro generating plants are extremely clean operations therefore there are almost zero emissions as a result of the production of electricity. Many Ontario electric generating plants are fired with natural gas or coal. These are definitely not zero emission operations.

Propane

5.4 General. LPG is a mixture of petroleum and natural gases whose primary constituent is propane. It is produced as a by-product of natural gas processing and petroleum refining. It is normally a gas, but when used in vehicles (and B-B-Qs) it is slightly pressurized and condenses to a liquid. In a gaseous state it is heavier than air and tends to collect in low-lying areas.

5.5 Current Status. LPG has been used in vehicular applications for many years. It is contained in pressurized tanks or cylinders (at about 300 psi) in liquid form. They must be inspected every 10 years, more frequently if exposed to the elements. Propane has experienced operational problems during cold
temperatures. This is however directly related to the level of technology used in the fuel system. Vehicles with modern, closed-loop, feed back-systems work as well as conventional gasoline systems when treated the same way as gasoline vehicles. Mechanics require special licensing and there are storage and maintenance precautions required to ensure the heavier-than-air fumes do not collect in building low points. Although a popular ATF in automobiles and light trucks, fuel price increases and the additional cost of the propane fuel system have resulted in a steady decline in the number of propane vehicles in Canada from a high of approximately 250,000 to 120,000. The propane infrastructure is widespread in Canada; hence availability is not a real problem.

Natural Gas

5.6 General. Natural gas is composed primarily of methane with a mixture of other hydrocarbons. It is derived from gas wells or in conjunction with crude oil programmes.

5.7 Emissions. Emissions from CNG vehicles are between 79% and 83% lower than gasoline-fuelled vehicles. CNG buses can cut NOx emissions by 38 to 58% and particulate matter by 40 to 86% compared to diesel-fuelled buses (Inform, p. 5). This study (Inform 2000, p. 8), showed mixed emission results from hybrid diesel electric buses compared to CNG buses. Using low sulphur diesel and particulate trap technology, the PM levels were comparable. CNG GHG production is 25% less than diesel (see table 2).

5.8 Current Status. When used in vehicles CNG is stored in high-pressure cylinders at about 3600 psi in gaseous form. These high-pressure cylinders are heavy and expensive. They must be inspected every five-years. In a gaseous state CNG is lighter than air. Vehicles with modern, closed-loop, feed back-systems work as well as conventional diesel and gasoline systems when treated the same way as these vehicles. Mechanics require special licensing and there are storage and maintenance precautions required to ensure that the lighter-than-air fumes do not collect in building high points. Due to its availability, CNG is currently the ATF of choice in the United States; hence most of the work being done on heavy vehicles and buses is centered on CNG or Liquid Natural Gas (LNG). LNG requires cryogenic cooling; this technology as applied to the vehicle industry is not fully matured and will not be considered in this report. Natural gas fuel prices have been dramatically increased over this past year, but bulk delivery prices are still relatively low and stable. The existing natural gas infrastructure has been placed to utilize natural gas as a heating fuel for buildings. Therefore if a building is heated by natural gas there is an assured supply of this fuel unlike propane, which must be delivered to its destination by vehicle. There are currently four commercial CNG refueling stations in the City of Ottawa (Eagleson and Katimivik, Merivale and Slack, Bronson and Gladstone and St Laurent and Belfast).
Ethanol

5.9 General. Ethanol is an alcohol derived from biomass such as corn, sugar cane, grasses, trees and agricultural waste and is therefore classified as a renewable fuel. The domestic resource base for ethanol production is vast.

5.10 Emissions. It is less photo chemically reactive than carbon based fuels and depending on its method of production, emits less HC, CO and NOx in vehicle applications.

5.11 Current Status. Ethanol is commercially available in Canada. However, most production is presently destined for the brewing industry. Two Federal government departments have opened E85 (15 percent gasoline and 85 percent ethanol) stations in Ottawa, the only ones in Canada. Ethanol is susceptible to water. As this commonly contaminates the fuel in pipelines, ethanol is presently delivered by tank transporter and blended on site. Low-level ethanol blends can be used in most gasoline engines with no engine or fuel system modifications required. To use an E85 blend in vehicles requires non-rubber lines and seals. An Ottawa based company Iogen, is experimenting with a different production technique. If successful, ethanol can be produced from less expensive agricultural and forestry waste products. This method has the added advantage that its full fuel cycle produces less CO2. The experimental facility is expected to come on-line in the near future, although commercialization would require a new facility to be constructed. This could assure availability of price-competitive ethanol.

Hydrogen

5.12 General. Many consider hydrogen to be the fuel for the 21st century. It is important to note that hydrogen is not a primary source of energy. In that sense, it has to be compared to electricity that is a converted form of energy.

5.13 Current Status. Hydrogen is currently produced, but only in limited quantities for niche markets. Hence there is no “distribution system”, such as exists for petroleum products. On-vehicle production (reformulation) is seen as an interim step, with gasoline and methanol as feedstocks. This adds to the cost and complexity of hydrogen-fuelled vehicles. Alternatives to reformulation include storage in pressurized tanks similar to CNG and storage in containers containing gas-adsorbing materials.

Biodiesel

5.14 General. Biodiesel can be made by chemically combining any natural oil or fat with an alcohol such as methanol or ethanol. It is therefore classified as a renewable fuel. It can be used in its pure form or as a blend with normal diesel fuel. Pure biodiesel is non-toxic, essentially free of sulfur and aromatics and degrades about four times faster than normal diesel. Biodiesel is most often
commercialized as a blend of 20 percent biodiesel with 80 percent petroleum-based diesel. Biodiesel has similar physical and chemical properties to diesel but has high levels of oxygen, a higher cetane number and a viscosity approximately twice that of petro-diesel. A 20 percent blend of biodiesel with petro-diesel raises the cold weather properties at least 3°F (cloud point, cold filter plugging point). Solutions to biodiesel winter operability problems are the same solutions that are used with conventional #2 petro-diesel (use a pour point depressant, blend with #1 diesel, use engine block or fuel filter heaters on the engine, store the vehicles near or in a building, etc) (National Biodiesel Board 2001, p1). B20 has almost 98% of the energy content of petro-diesel.

5.15 Emissions. Engine emissions of particulate matter are reduced by 31%, carbon monoxide by 21% and total hydrocarbons by 47%. However, nitrogen oxide emissions are increased. (Transportation Issue Table, p. 84). For a B20 blend, particulate matters are reduced by 8%, carbon monoxide by 9%, and total hydrocarbons by 14%. NOx is increased by 1% (National Biodiesel Board p.1). B20 blend reduces CO₂ emissions by 15% (National Renewable Energy Laboratory).

5.16 Current Status. Biodiesel and biodiesel blends have been extensively tested in Canada as well as the United states. Performance and drivability have been shown to be similar to conventional petro-diesel. A Canadian Renewable Fuels Association led consortium is currently performing cold weather testing with the City Of Montreal and Maple Leaf foods in Montreal. The results of these tests should be of great interest to the City of Ottawa. Due to the current high crude vegetable oil prices, biodiesel is not commercially available in Canada. Current quoted B20 prices in the US are from 8 to 16 cents (Canadian) per liter extra (Equipment Manufacturers Institute, p.4).

E-Diesel

5.17 General. E-diesel is blend of diesel fuel and ethanol (see paragraph 4.9) with a blend stabilizer. The addition of ethanol to diesel fuel will affect some of the key properties of diesel; these include viscosity, lubricity, energy content and cetane number and flash point. Minimum specifications are required to ensure that fuel injection system durability is not compromised and that engines are able to start reliably when hot. As there is an inverse relationship between cetane number and octane number, the addition of ethanol will reduce the cetane number. The energy content of diesel is decreased by approximately 2% for each five percent addition of ethanol by volume (ASAE 2001, p 6). This will result in an equivalent lowering of the engine power. Low-level ethanol blends can be used in most diesel engines with no engine or fuel system modifications required. Inclusion of ethanol in diesel will aid cold weather starting.

5.18 Emissions. Reductions in PM have been consistently shown (ASAE, p 12), but the reduction of other emissions is less clear. A summation of previous work in that ASAE paper states that for a 10 percent blend “a consistent reduction in the
PM of 20 to 27 percent and reductions in NOx from 0 to 4 - 5%”. CO is reduced by 10 to 25% and NOx by 2 to 10%.

5.19 **Current Status.** E-diesel is not presently commercially available in Canada. Both the Canadian Renewable Fuels Association and Sunoco are advocating its production and use (see paragraph 8). Current quoted e-diesel prices in the US are from 2.1 to 2.9 cents (Canadian) per liter extra (Equipment Manufacturers Institute p.4).
6.0 MOTIVE POWER

Hybrid Vehicles

6.1 General. A Hybrid-Electric Vehicle (HEV) uses an internal combustion engine or fuel cell in conjunction with an electric motor(s) and a battery pack. In a “series” configuration, the engine is used to drive a generator that in turn charges the storage device to power the motor. In a “parallel” configuration, the engine only operates when the batteries required charging or when extra power is required for climbing hills or traveling at highway speed. A regenerative braking system recharges the batteries during the breaking operation. The engine operates at a relatively constant speed; hence operating conditions can be optimized to minimize emissions and fuel consumption. Hybrid engines are typically smaller than their conventional counter part. The battery pack is also smaller than a traditional all-electric vehicle. Total weights for a hybrid diesel electric vehicle is between that of a conventional diesel vehicle and an all-electric vehicle. As a transitional vehicle, HEVs can easily co-exist with today’s vehicles, using the current infrastructure. As in all alternative fuel vehicles, fuel savings pay for the added costs of the new system. Urban transit buses are usually kept for a long time (see paragraph 1.4); hence break-even or payback situations are possible.

6.2 Emissions. Hybrids have been also tested in Boston, where the Massachusetts Bay Transportation Authority has logged about 35,000 miles on a pair of Orion VI buses. The engine is fitted with a particulate filter. This configuration dramatically reduces emissions while improving fuel economy by 25% to 50% and improving performance. According to the Union of Concerned Scientists, “emissions of soot and the pollutants that cause smog are 40 percent below those of the diesel buses they replace”. When compared to conventional diesel, HEVs have the potential to lower GHG emissions by approximately 25%. When compared to conventional diesel buses, NOx is reduced by 31 to 46 % (Inform, p.6).

6.3 Current Status. New York City Transit first used hybrid buses in 1998 with a fleet of ten Orion buses that used the HybriDrive™ system. To date, those buses have accumulated more than 300,000 miles in revenue service, mostly on congested routes in Manhattan (Alternative Fuel News May 2001, p. 4). The MTA Transit plans to add 325 more buses to its fleet between 2001 and 2004 at a cost of $750,000 Cdn each. Batteries are currently expensive and add considerable weight to the vehicle. The Prius passenger car by Toyota has been offered in Canada for the past two years. It is a 4/5 passenger automobile than delivers approximately twice the fuel economy of its North American counterparts, but costs twice as much to purchase.
Fuel Cells

6.4 General. The hydrogen fuel-cell is one of the most promising technologies with respect to reduction of GHG and other emissions. It produces DC electricity in an electrochemical process to power a variable speed electric propulsion motor(s). The technology is applicable to both light and heavy vehicles. When pure hydrogen is used in fuel cells, a zero-emission vehicle can result. If “clean” processes for production of hydrogen can be developed to the necessary state, full fuel cycle emissions would be negligible.

6.5 Description. A fuel-cell electric vehicle uses fuel cells instead of batteries to supply power to the electric vehicle motor. Like batteries, fuel cells use a chemical reaction to produce electrical power, but in fuel cells the reactants (i.e., fuel) are introduced from an external source. As long as fuel is supplied, fuel cells can operate continuously. Instead of needing to be recharged (as with a battery) a fuel cell need only be refueled. The “reactants” of most fuel cells are hydrogen and atmospheric oxygen. These two elements combine with a catalyst to produce electricity and water. One of the key advantages of fuel-cell technology is its ability to utilize a wide range of energy resources in a clean and efficient way. From a performance perspective, a fuel-cell vehicle offers the following:

- excellent range
- the ability to refuel rapidly
- simple, quiet operation (few moving parts)
- high energy density (power to weight ratio)
- near zero emission from the vehicle
- low total fuel cycle emissions (depending on the fuel source).

6.6 Current Status. Most fuel-cell vehicles currently in use are experimental buses that carry tanks of compressed hydrogen gas as their fuel. Several companies have successfully demonstrated on-board fuel reforming systems that allow for the use of conventional liquid fuels. Most major automobile manufacturers are researching and developing fuel-cell technology. Daimler-Benz has produced a fuel-cell vehicle that reforms methanol on-board, thereby eliminating the need for hydrogen tanks. Chrysler has also eliminated the need for hydrogen gas tanks with its new on-board reformed gasoline-powered fuel cell. Toyota is showing a fuel cell that can power a 45 kW motor, and has developed a new hydrogen adsorbing titanium alloy storage system that can store 5 times more hydrogen than cylinder storage of the same volume. Xcelisis is a joint venture set up by Ford, Daimler Chrysler and the fuel cell company Ballard Power Systems to produce fuel cell engines. The organization is set to deliver 30 Mercedes fuel cell buses for commercial use as early as the end of next year. In May 2001, Singapore’s Economic Development Board (EDB) announced that Daimler Chrysler had agreed to co-operate on the launch and implementation of a fuel cell vehicle demonstration and development project. The NECAR – no emissions car – is
being tested on Singapore’s roads, and is expected to be available for sale to the public in 2004. In this latest development, BP will develop and supply the required hydrogen-refueling infrastructure for clean fuel cell cars equipped with hydrogen-fuelled fuel cell power trains. There are still a number of problems that stand in the way of commercial production of fuel cell vehicles. The current cost of a fuel cell engine is in the region of $1,070 per kW, compared to around $31 per kW for an internal combustion engine. There are many “missing links” in development of a hydrogen infrastructure. Major barriers and uncertainties include:

- Hydrogen safety - codes and standards are at an early stage
- Cost and performance of fuel cells is unclear - mass production is being studied by General Motors, Ford and others
- Transmission and distribution of hydrogen is expensive, compared to natural gas
- Plastic pipe and metal fittings etc. in natural gas pipelines are not compatible with hydrogen
- Economic incentives for shifting to hydrogen are not present; there is no transmission and distribution system, since hydrogen is not in widespread use.

6.7 Time Line To Market. A hydrogen distribution infrastructure to support hydrogen fill-up does not exist at this time. Steam reforming and hydrogen extraction from industrial process byproducts are mature technologies. Reformers for use on vehicle-scale already exist, but further development will continue in parallel with development of fuel cell vehicles. The preferred energy scenario is direct use of hydrogen for vehicle fuel cells and other applications. The criteria for “on-board” storage of hydrogen include cost, weight and size. Compressed gaseous hydrogen or liquid hydrogen do not meet these criteria, but advanced technologies for solid storage of hydrogen are under development which appear capable of meeting these goals by the mid 21st century or sooner. Given the large amount of resources devoted to fuel-cell research and development, there is reason to believe that this technology could provide a tremendous contribution to GHG mitigation by 2030 by being applied to light vehicles, mass transit and heavy vehicles.

Propane

6.8 Description. Initially LPG engine were modified gasoline and diesel engines. The level of technology applied to the conversion was not great. Conversion was done solely for economics. This resulted in vehicles that were not much cleaner than the original gasoline or diesel engine. Since approximately 1995, high-level technology kits have been available and their use has resulted in vehicles that operate much cleaner than gasoline or diesel engines. For the past several years Original Equipment Manufacturers have produced vehicles that are much cleaner than their gasoline counterparts. This was initially seen in passenger cars, vans and pick-up trucks.

6.9 Current Status. Until about 1990, LPG vehicles were the most common alternative fuel vehicles in North America. Since that time the number of vehicles
in Canada alone has decreased by 50 percent. This is due to the fact that the US considers it a “foreign source” fuel. The cost of LPG is tied directly to the cost of petroleum products (see paragraph 4.4). Over the past few years the greater demand for oil (heating and diesel) has reduced the amount of LPG available and this has driven up its cost. LPG is now almost exclusively used in Canada, but there are exceptions. Ford produces some LPG light trucks. In 1998 San Antonio, Texas, purchased 66 new 30-foot propane-powered buses and 5 new propane-powered streetcars. The bus fleet was powered by propane in the 1950s and 1960s and started using propane again 4 years ago in its service and Para transit fleets. The new buses are equipped with the Cummins B5.9 LPG low emissions vehicle (LEV) engines. The LPG buses will compliment the 209 LPG powered vehicles already in the VIA fleet. The transit authority has had a very favorable experience with propane vehicles and has learned how to maintain and refuel its propane fleet. They were pumping about 4,500 gallons of propane a night before the new buses, which increased to more than 9,000 gallons a night with the new propane buses (Alternative Fuel News Vol 4, p 2).

Natural Gas

6.10 Description. The use of CNG has been growing in popularity since the early 1990s. Initially CNG engine were also modified gasoline and diesel engines. The level of technology applied to the conversion was not great. Conversion was done solely for economics. This resulted in vehicles that were not much cleaner than the original gasoline or diesel engine. Since approximately 1995 high-level technology kits have been available and their use has resulted in vehicles that operate much cleaner than gasoline or diesel engines. For the past several years Original Equipment Manufacturers have produced vehicles that are much cleaner than their gasoline counterparts, particularly where CNG is the only fuel (vice bi-fuel operations). This was initially seen in passenger cars, vans and pickup trucks.

6.11 Emissions. A summary of work completed by the Union Of Concerned Scientists in a 1998 report detailed the following: “new conventional diesel bus technology represents an improvement over older buses for both PM and NOx emissions. Further, the hybrid diesel bus achieved reductions in NOX. The conventional CNG bus registered the least amount of pollution for both PM and NOx. PM emissions were 67 percent lower in the CNG bus compared to the diesel hybrid. NOx emissions dropped 25 percent in the CNG bus” (Inform, p. 67). Hydrocarbons are reduced by 30 to 60 percent (Northeast Advanced Vehicle Consortium).
6.12 **Current status.** Ford, Daimler Chrysler and General Motors produce a range of CNG powered automobiles, vans and pickup trucks. Four out of five of the top US bus manufacturers build significant numbers of CNG buses (Inform p. 5). Sixty-five transit agencies in United States currently operate CNG buses. The Los Angeles Metropolitan Transit authority has an inventory of 569 CNG buses and plans to add more than 2000 buses, mostly CNG, by 2004. Many heavy truck manufacturers offer CNG optional engines (Alternative Fuel News, May 2001 p 4).
7.0 INFRASTRUCTURE AND VEHICLES

Infrastructure

7.1 Cost of ATF Infrastructure. In the context of this review, infrastructure can be defined as: refueling facilities and repair/maintenance facilities. The relevant costs associated with infrastructure are: the cost to install a commercial refueling facility and the cost to equip a facility and train the mechanics to service ATF vehicles. In the case of LPG and CNG, training costs for mechanics are typically $2500 each. Shop tools are in the order of $2500. Depending on the type of alternative fuel selected and geographical location, some fuel companies will install a refueling station(s) with no capital outlay by the customer. Based on projected fuel usage, the fuel price is adjusted so that the capital costs are recovered over a predetermined period of time. The contract usually also requires a minimum fuel purchase per month or per year.

CNG

7.2 Over Night Refueling. CNG refueling facilities can range from a Vehicle Refueling Apparatus (VRA) to a full-scale station. The VRA is classified as a slow fill solution that can re-fuel two vehicles (cars, vans or pick-up trucks) over night. Their use is limited to vehicles that have a significant downtime. Typical costs include $4000 for installation and $4000 for equipment purchase or a monthly rental of $60.

7.3 Cascade Fill. This involves a compressor, storage tanks and fuel dispensers. A low-cost cascade system utilizes a small compressor to fill a series of tanks. This reduces the fill time for an individual vehicle but the system is limited to the number of vehicles that can be filled due to tank capacity. Typical station costs are in the order of $200,000.

7.4 Fast Fill. This represents a full-blown filling station. Large compressor(s) pressurize the gas to approximately 3600 psi. Refueling time is approximately the same as for gasoline or diesel. Typical costs are $7.5 million to $40 million per site for a 30 bus per hour capacity (Northeast Advanced). Garage upgrades, mostly safety features are $15 to $65 million. Indoor refueling is possible at an additional cost of $1 million to $2 million.

LPG

7.5 There is a range of filling stations options available. The costs are directly proportional to the number of dispensing units required. A multi-vehicle filling station costs in the order of $1 million. Refueling time is approximately the same as for a gasoline or diesel vehicle. Garage updates are typically $500,000. Indoor refueling is not possible.
E-Diesel

7.6 Low-Level Blend. A typical installation for a 10% ethanol, 90% diesel blend only requires the addition of an ethanol tank or the conversion of an existing tank to hold the ethanol. A pump splash blends the fuel when it is being dispensed. Typical costs are in the order $10,000 for tank cleaning to $125,000 for a new tank (above ground installation). Safety precautions must be revisited as the addition of ethanol reduces the flashpoint.

Vehicles

7.7 General. The fuel cost price differential, assuming it is in favour of the alternative fuel, is what pays for the extra cost of the alternative fuel vehicle. The more kilometers a vehicle accumulates during its lifetime, the more likely savings in fuel will pay for the extra cost of the vehicle.

7.8 Light Vehicles. CNG and LPG automobiles, vans and pick-up trucks are available from OEMs and cost of between $3,500 and $10,000 more than their gasoline counterpart. High-technology conversion kits are available for both CNG and LPG at a cost of between $3,500 and $6,000. One factor not presently evaluated is the effect the on-board alternative fuel equipment will have on the selling price of a remarketed vehicle. Some funding offsets are available to reduce the extra costs of the alternative transportation fuel vehicle and depend on method of vehicle procurement; the alternative fuel selected and deployed geographic location. For example on some pick-up truck models, fleet discount of $2000 are available; some utility companies provide a $1,000 or $500 rebate depending on whether it is an OEM alternative fuel vehicle or an aftermarket conversion. Provinces provided a rebate on PST. In 1999, in Toronto, a combination of all of these rebates reduced the additional cost of a mono-fuel CNG Crown Victoria taxi from approximately $6,500 to a mere $88.

7.9 Buses and Heavy Trucks. CNG and LPG buses and trucks are available at an additional cost of between $35,000 to $50,000. Hybrid diesel buses are presently $350,000 more than their diesel counterparts. These vehicles usually accumulate many more kilometers than light vehicles. Hence fuel cost savings play more of a part in the cost effectiveness equation. Capital cost offsets are limited and may only include fuel company and PST rebates.
EMERGING DIESEL POLLUTION REDUCTION TECHNOLOGIES

8.1 General. Diesel emission control technologies are designed to reduce emissions of nitrogen oxides and particulate matter from buses and heavy trucks. These technologies can be used to retrofit an existing bus or can be incorporated into future buses. The two most common retrofit technologies are diesel particulate traps and diesel oxidation catalysts. These and other certified technologies have shown during dynamometer testing, to have the potential to reduce particulate emissions by as much as 80% (Environmental Fact Sheet p.18). Testing on actual buses has shown significant PM, CO and HC reductions (Urban Driving Cycle Results p21). Some of these technologies/specific models require the fuel to be of the ultra low sulphur type, 30 to 50 ppm.

8.2 Particulate Traps. Diesel particulate traps reduce emissions of particular matter by filtering them out of the exhaust stream and cleaning the filter by using oxidation catalysts or burning the trapped particulates. This regeneration of the filter avoids the problem of clogging that plagued the first generation of particulate traps.

8.3 Oxidation Catalysts. The oxidation catalysts oxidize nitrogen oxide to nitrogen dioxide that destroys the soot trapped in the walls of the filter. They require the use of low sulphur fuel to function properly. Diesel oxidation catalysts also reduce particulate emissions by oxidizing carbon monoxide, gaseous hydrocarbons and liquid hydrocarbons adsorbed onto carbon particles in diesel exhausts. They have proven effective in reducing particulate emissions in older buses (Bus Futures p. 36).

8.4 Retrofit Program. The United States Environmental Protection Agency (EPA) has introduced a Voluntary Diesel Retrofit Program. A Verification Process is used to introduce certified technologies to the market as cost effectively as possible, while providing customers confidence that verified technologies will provide emission reductions as advertised. This verification process evaluates the emission reduction performance of retrofit technologies, including their durability, and identify engine operating criteria and conditions that must exist for these technologies to achieve those reductions. The information from this program is of benefit to Canadian vehicle owners wishing to retrofit diesel vehicles.

8.5 Certified Technologies. There are currently five manufacturers who have oxidation catalysts certified by EPA. Technologies to reduce NOx emissions are under development. They include cooled exhaust gas recirculation, selective catalytic reduction systems area and NOx adsorbers. Many of these systems are under test with integration into new engines expected in 2002 to 2007. In the cases where particulate traps and oxidation catalysts are used, they replace the existing mufflers etc. Where other technologies are used, they are retrofitted at the time of engine rebuild. The following table contains a select listing from their current listing (Office of Air and Radiation 2001, p. 1):

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Technology</th>
<th>PM%</th>
<th>CO%</th>
<th>NOx%</th>
<th>HC%</th>
</tr>
</thead>
</table>


Table 4 – Retrofit Manufacturer, Technology and Percentage Reduction of Pollutants

8.6 Costs. The EPA commissioned an independent cost survey for these technologies. The report, dated 5 December 2000 gives the following “mean” cost estimates for production quantities of 1,000 (US dollar conversion $1.50):

a. a. Replacement Oxidation Catalysts - $2400
b. b. Diesel Particulate Filters - $7500
9.0 RECENT APPROACHES TO THE CITY OF OTTAWA

**Canadian Renewable Fuels Association**

9.1 The Canadian Renewable Fuels Association (CRFA) has approached the City to participate in a trial of an ethanol-diesel fuel blend. This trial commenced end-November, with Environment Canada conducting engine performance tests of fuel blends and a thorough exhaust gas analysis of the test fuels. If the initial tests are successful there will be, subject to approval, an on-road test of the fuel in transit buses. The trial is scheduled to last for approximately one year.

**Sunoco**

9.2 Sunoco, the current fuel supplier to the City, has informally approached the City to consider use of ethanol blended diesel, bio-diesel and water-diesel emulsions. A presentation to the City was scheduled for July of this year but this did not materialize. As Sunoco is presently the major diesel supplier to the City, this presentation should be scheduled.

**Canadian Farm Business Management Council**

9.3 Earlier this year a meeting was held involving Madeleine Meilleur and James Laws, the Executive Director of the Canadian Farm Business Management Council. Subsequent correspondence indicated an informal invitation had been extended to this Council and the manufacturers of biodiesel to speak with the Transportation of Committee. A firm request for presentation should be made, as this will be a good introduction to trials on biodiesel being done by the City of Montreal.
### 10.0 CONCLUSIONS AND RECOMMENDATIONS

**Summary**

10.1 The following table summarizes the costs and benefits associated with the various engine/fuel options:

<table>
<thead>
<tr>
<th>Technology</th>
<th>Time To Market</th>
<th>Additional Cost Of Bus</th>
<th>Additional Infrastructure Per Location</th>
<th>Relative Fuel Costs Per GLE</th>
<th>Environmental Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel</td>
<td>0</td>
<td>0</td>
<td>$0.46* Base Line</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Cell</td>
<td>20 Years</td>
<td>++</td>
<td>++</td>
<td>?</td>
<td>Base Line</td>
</tr>
<tr>
<td>Hybrid</td>
<td>5 Years</td>
<td>$350K</td>
<td>$0.28**</td>
<td>-25%</td>
<td>-40%</td>
</tr>
<tr>
<td>CNG</td>
<td>Now</td>
<td>$50K</td>
<td>$0.35</td>
<td>-25%</td>
<td>-30 to - 60%</td>
</tr>
<tr>
<td>LPG</td>
<td>Now</td>
<td>$50K</td>
<td>$1.5M</td>
<td>-10%</td>
<td>-50%</td>
</tr>
<tr>
<td>E-diesel blend</td>
<td>Soon</td>
<td>0</td>
<td>$125K</td>
<td>-0 to - 10%</td>
<td>-10 to - 25%</td>
</tr>
<tr>
<td>Biodiesel blend</td>
<td>Now</td>
<td>0</td>
<td>$0.58</td>
<td>-15%</td>
<td>-14%</td>
</tr>
<tr>
<td>Particulate Traps</td>
<td>Now</td>
<td>$7.5K</td>
<td>+2%</td>
<td>N/A</td>
<td>-60%</td>
</tr>
<tr>
<td>Oxidation Catalysts</td>
<td>Now</td>
<td>$2.4K</td>
<td>0</td>
<td>N/A</td>
<td>-20 to - 60%</td>
</tr>
<tr>
<td>Ethanol (10) (Gasoline)</td>
<td>Now</td>
<td>N/A</td>
<td>$10K</td>
<td>+$0.02 Gasoline</td>
<td>-3.9%</td>
</tr>
</tbody>
</table>

*Based on diesel at $0.60 per liter
** Based on 40% improvement in fuel economy.

Table 5 – Fuel/Engine Cost and Benefit Comparison

**Conclusions**

10.2 All forms of on-road transportation are getting cleaner in response to more stringent emission regulations. However, there are many vehicles, particularly buses in-service in the City of Ottawa that, although compliant with the emission regulations of their day, require upgrading to reduce these harmful emission levels.
10.3 Cleaner burning fuels have been the first approach to solving these pollution problems. Ethanol, propane, CNG, hydrogen, biodiesel and e-diesel can all be burnt in engines with varying degrees of modifications to the engine.

10.4 Only e-diesel and biodiesel can be used without costly modifications or additions to existing infrastructure. With a high-level biodiesel blend, engine emissions of particulate matter are reduced by 31%, carbon monoxide by 21% and total hydrocarbons by 47%. However, nitrogen oxide emissions are increased. In low-level blends they do not require modifications to the engine. Emission reductions are only in proportion to the blend level and cannot be compared to those resulting from a total fuel replacement. Commercial availability of biodiesel is limited. E-diesel is not commercially available and only blended for testing of specific stabilizer.

10.5 CNG as a fuel for urban buses and a good cross section of other vehicles has been the subject of many evaluations. In the United States it is the ATF of choice for buses and light vehicles. In Ontario, the natural gas distribution is widespread, but only as a source of heating fuel, not vehicle fuel. Refueling infrastructure is costly and requires a long-term commitment. Natural gas buses can cut NOx emissions by 38 to 58%, CO by 19.5%, PM by 40 to 86%, and CO2 emissions by 25% compared to diesel-fuelled buses.

10.6 Propane, once the alternative fuel of choice in Canada, has experienced a loss of vehicle market share in Canada and the United States and fewer propane vehicle choices are available today as opposed to ten years ago. Propane buses and other heavy-duty vehicles are very scarce. The propane infrastructure is widespread in Ontario, but final delivery is still made to the refueling station by vehicle. Although refueling infrastructure is not as costly as that of CNG, it still requires a long-term commitment.

10.7 Hydrogen is used as the fuel for fuel cells. Fuel cell vehicles are the acknowledged “way ahead”. They will be virtually zero emission vehicles, depending on the source of hydrogen. No infrastructure exists to get it to useful locations. In Ontario, there are no hydrogen refueling stations. As an interim measure, it will be produced by on-board reforming units that are fueled by gasoline, ethanol or methanol. However, they are not yet commercialized.

10.8 Two hybrid electric automobiles are currently being sold in Japan and North America. They cost approximately twice as much as their gasoline counterparts. Hybrid electric buses are in limited use in the United States. Initial trials have shown positive results and follow-on buys are being made. Operating costs are unknown. Their performance in an Ottawa winter is also unknown. A hybrid diesel bus has the great advantage of requiring no modifications to existing infrastructure and no new infrastructure. When compared to conventional diesel, hybrid diesel vehicles have the potential to lower PM by 40%, NOx by 31 to 46%,
CO by 40% and HC by 40% and GHG emissions by approximately 25%. This translates into a reduction of 23,000 tons relative to 2002 projected operations.
The substitution of E 10 for regular gasoline in the City’s operations will reduce emissions annually by 1 tonne of CO, 1 tonne of NOx and 250 tonnes of CO₂.

Recommendations

10.9 **Long Term (20 years).** The long-term implementation strategy for the City of Ottawa should be the utilization of fuel cell vehicles. When they are commercialized, fuel cell vehicles should replace vehicles in service, as they are withdrawn.

10.10 **Mid-Term (5 to 10 years).** The mid-term implementation strategy for the City of Ottawa should be the utilization of hybrid diesel buses. Hybrid diesel electric projects should be monitored, particularly the New York City project. When commercialized, hybrid buses and trucks should replace diesel ones, as they are withdrawn from service.

10.11 **Short Term (To 24 months).**

10.11.1 The City should continue to give its full support to the e-diesel test that is currently under way. If the results are positive, its cost-effectiveness should be determined.

10.11.2 The Montreal biodiesel project should be monitored to see if CO₂ reductions warrant further investigation.

10.11.3 The cost benefit of new generation particulate traps and oxidation catalysts should be investigated for possible inclusion in new buses and retrofit of old buses – approximate cost for retrofit of 400 buses would be $3M.

10.11.4 E10 (gasoline) should be used in all gasoline vehicles – approximate cost $80 K per year.
REFERENCES


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4. EPA (March 1997), Environmental Fact Sheet: Office Of Mobile Sources


17. Transportation Issue Table National Climate Change Process (December 24, 1999), *Alternative And Future Fuels and Energy Sources For Road Vehicles*, Ottawa, Ministry of Supply and Services.

18. SAE 970186 (February 1997), *Urban Driving Cycle Results Of Retrofitted Diesel Oxidation Catalysts On Heavy-Duty Vehicles: One Year Later*, SAE Warrendale.

Annex A
Emission Reduction Paper

CITY OF OTTAWA VEHICLE DISTRIBUTION

<table>
<thead>
<tr>
<th>Type</th>
<th>Diesel</th>
<th>Unleaded (Including Ethanol Blend)</th>
<th>Propane</th>
<th>Electric</th>
<th>Natural Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>198</td>
<td>892</td>
<td>53</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Medium</td>
<td>315</td>
<td>27</td>
<td>4</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Heavy</td>
<td>1405</td>
<td>13</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>1918</td>
<td>932</td>
<td>58</td>
<td>16</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes:

Light – Automobiles, Pick-up trucks, cargo vans, 3-ton trucks, Police cars, motorcycles and ice-resurfacers.

Medium – Backhoes, crew cab dump trucks, step-vans, paint trucks, spreader trucks, dump trucks and solid frame tractors.

Heavy – Tandem dump trucks, tandem snow plows, graders, transit buses, front end loaders, fire trucks, aerial lift trucks and refuse packers.

Propane – Vans, ½ ton pick-ups, forklifts and ice resurfacers.

Natural Gas – ½ ton pick-up truck.

Electric – Sweepers, forklift and utility carts.