CEP Action Area Studies
City of Yellowknife Fleet Review

Aboriginal Engineering Ltd.

Prepared for:
The City of Yellowknife

Prepared by:
Aboriginal Engineering Ltd.

June 2nd, 2006

CEP Action Area Studies
City of Yellowknife Fleet Review

Prepared for:
The City of Yellowknife

Prepared by:
Aboriginal Engineering Ltd.
Unit 20, 100 Borden Drive
Stanton Plaza, Box 133
Yellowknife, NT
X1A 2N1

June 2nd, 2006

Acknowledgments

The authors of this report would like to thank Dennis Althouse, Works Superintendent for the City of Yellowknife, as well as Michael Gannon, City Energy Coordinator, and Andrew Robinson of the Arctic Energy Alliance.

Executive Summary

The City of Yellowknife's fleet is used for performing various public services such as bylaw enforcement, construction, public works, etc. Analyzing fuel consumption data it is estimated that the annual fuel consumption for the City's fleet is 160,426 L of diesel and 108,544 L of gasoline, resulting in a total of 713,770 kg CO_{2e} of greenhouse gas emissions (GHG). It was found that significant fuel consumption and GHG emissions result from sub-contracted activities such as trucking water and sewage to/from Old Town and Latham Island – which results in an equivalent to 57-65% of the total fleet diesel consumption. The City could reduce overall GHG emissions by implementing all-weather piping systems for water and sewage for Old Town and Latham Island.

A review of other fleet management strategies in northern climates (Whitehorse, AK and Anchorage, AK) has shown that anti-idling campaigns in northern climates have failed. Although public awareness campaigns have been implemented, fleet managers have noted that drivers continue to idle to remain warm in their cars. Whitehorse has implemented a driver training program and has seen gains in fuel efficiency, while Anchorage has introduced compressed natural gas (CNG) vehicles into its fleet.

Different measures to increase fuel efficiency within the fleet operations have been presented in the report. Firstly, fuel-efficient vehicles have been proposed for use as bylaw vehicles. Hybrid vehicles and *Smart Cars* were found to be the most feasible for use as bylaw vehicles, and despite their compact size, such vehicles have been used as bylaw vehicles in the City of Brampton ON. These fuel-efficient vehicles could exhibit high annual savings when compared to the current vehicles used as bylaw vehicles.

With respect to maintenance and training, the implementation of a driver training program would realize the highest gains in fuel efficiency. Driver training programs, modeled after the *Fuel Sense* program developed by the City of Yellowknife incorporate optimal acceleration and braking rates, with general vehicle maintenance to achieve high gains in fuel efficiency. The

City of Yellowknife could use training materials available online from the Natural Resources Canada (NRCan) Office of Energy Efficiency (OEE), or potentially send supervisors for driver training organized by the OEE to achieve gains in fuel efficiency for the City's fleet of vehicles and equipment.

Anti idling technologies were considered for use within the City's fleet of vehicles and equipment. Direct fired heaters would be most applicable for the City's light trucks, and larger heavy-duty Auxiliary Power Units (APU) would be applicable to heavy equipment. Using assumptions on the amount of fuel spent idling, it was found that currently the anti-idling technologies face long paybacks; however the payback periods would be significantly reduced given the current escalation rate in fuel prices.

Renewable fuels were also considered to displace quantities of diesel and gasoline fuel used by the City. Bio-diesel could replace 5% of the overall diesel consumed by the fleet, with no major modifications to vehicles and equipment. Ethanol for addition to gasoline would require more modifications, and thus bio-diesel would be the most feasible option. It was found that a slight increase in fuel costs for purchasing bio-diesel could reduce the overall GHG emissions by 2.3%.

The table below shows the many options and measures that could be implemented to achieve increases in fuel efficiency, and decreases in GHG emissions. The preferred options are as follows:

1. Replace all 3 bylaw vehicles with 3 *Smart Cars;*
2. Implement a driver training program;
3. Install direct-fired heaters on all F-series trucks, APU units for heavy equipment; and
4. Replace 5% of petro-diesel with bio-diesel trucked from the south.

If all of these preferred options were adopted an overall decrease in GHG emissions of 17.9% would be realized. However, capital costs would be high, as can be seen in the table below, especially for the anti-idling technologies. Thus, it is recommended that all of the above options be implemented, except that one or two direct-fired heaters and one or two APU units could be purchased and monitored.

Table i Energy, GHG, and Financial impact of all options to reduce fleet fuel consumption

Measure	Energy Impact		Overall GHG Impact		Financial Impact	
	Diesel displaced (L)	Gasoline displaced (L)	kg CO2e	% reduction	Capital Cost	Annual Savings
Replace all 3 bylaw vehicles with 3 Honda Accord Hybrid vehicle	0	3,476	9,233	1.29%	$108,534	$2,742
Replace all 3 bylaw vehicles with 3 Honda Civic Hybrid vehicles	0	10,895	28,939	4.05%	$77,574	$8,592
Replace all 3 bylaw vehicles with 3 Toyota Prius Hybrids	0	12,311	32,702	4.58%	$76,086	$9,710
Replace all 3 bylaw vehicles with 3 *Smart Cars*	0	13,037	34,630	4.85%	$77,049	$10,282
Replace all 3 bylaw vehicles with 3 Honda Civic GX CNG Cars	0	6,789 GLE*	12,270	1.72%	$76,208	$3,652
Tire Maintenance	1,049	1,045	5,559	0.78%	negligible	$1,656.99
Preventative Maintenance	5,246	5,227	27,797	3.89%		$8,284.94
Energy-Conserving Motor Oil	2,833	2,821	15,006	2.10%	twice the cost of regular motor oil	$4,472.51
Driver Training	0	15,661	41,600	5.83%	Negligible costs for use of online resources, $60,000 start up, $42,500 per year afterwards for a formal training program	$12,351.84
Install Blue Heat fired heaters in F-150, F-250, F-350 trucks	0	3,617	12,491	1.75%	$2282 each, $70,750 total for 31 unit installations	$2,852.93
Install APU units on heavy duty trucks	4,196	0	11,127	1.56%	$8055 each, $69,811 for 8 unit installations	$3,328.86
Install APU on heavy equipment	4,255	0	11,284	1.58%	$8055 each, $52,358 for 6 unit installations	$3,375.75
Purchase 8,000 L bio-diesel per year to achieve overall 5% blend of bio-diesel	8,000	0	16,548	2.32%	Overall increase in diesel purchasing cost of $5,573	

Table of Contents

List of Figures

List of Tables

1.0 Introduction

The City of Yellowknife maintains a fleet of vehicles and equipment used for public service. As a part of the City of Yellowknife's Community Energy Plan (CEP), a goal is to reduce the City's fleet fuel consumption and greenhouse gas (GHG) emissions by 20% within 10 years. Goals of this report are to a) examine current fuel consumption for the City's fleet based on available data; b) examine options to reduce fleet fuel consumption; and c) quantify reduction in fuel consumption, GHG emissions, as well as financial impact of implementing the said options.

2.0 Background Information

Section 2.0 of this report presents an overview of the City of Yellowknife's fleet of vehicles and equipment, as well as calculated values for the following annual figures for the City's fleet: fuel consumption, GHG emissions, and energy consumption.

2.1 City of Yellowknife's fleet of vehicles and equipment

The City of Yellowknife's fleet includes light vehicles, bylaw vehicles, medium duty trucks, heavy duty trucks, heavy equipment, mobile tractors, emergency equipment, and other equipment (generators, etc.). The City's fleet is used for municipal enforcement, construction and public works, and emergency support. A full detailed list of vehicles and equipment is provided in Appendix A, and the breakdown is as follows:

- 55 Light duty vehicles
- 3 Bylaw vehicles
- 18 Medium duty trucks
- 16 Heavy duty trucks
- 15 Heavy duty equipment
- 60 Other (generators, heaters, etc.)
- 13 Mobile tractors
- 12 Emergency equipment

Fuel consumption data shows that not all of the vehicles and equipment are used annually. In some cases, some equipment might be used only sporadically and fueled from Jerry Cans. The tables in Appendix A provide make/model information for the eight classes of vehicles and equipment, as well as the fuel type.

The fleet of equipment excluding light vehicles, bylaw vehicles, medium and heavy duty trucks, is kept and maintained indoors at the City Garage which is heated, thus heavy equipment is not left idling at the end of the shift on extremely cold winter nights, as would be typical under construction projects.

2.2 Fleet Fuel Consumption and Greenhouse Gas Emissions

Fuel consumption data was obtained from the City of Yellowknife Works Superintendent. Fuel consumption data for each piece of equipment was recorded from June 1, 2005 – December 31, 2005, and data was separated between diesel and gasoline. A gross figure for total consumption of diesel and gasoline was obtained for the period of January 1, 2006 – March 15, 2006. In addition, bylaw vehicles and fire trucks fuel up most regularly at a separate cardlock, located at the Yellowknife Fire Hall. Fuel consumption data for the period of July 1, 2004 – June 30, 2005 was obtained. Together, these three data sources were combined to calculate a representative yearly fuel consumption for the City's fleet.

It is estimated that the City of Yellowknife's fleet annually consumes 160,426 L of diesel, and 108,544 L of gasoline. This results in a total of 713,770 kg CO_2 equivalent GHG emissions.

Peak fuel consumption occurs in the winter, as heavy equipment is used steadily for snow removal between mid-December and April. For calculation purposes, since fuel data is available for only January 1, 2006 – March 15, 2006, it shall be assumed that snow removal only takes place during this period of time. The period of January 1 – March 15 represents 20% of the days of the year. Table 1 below shows that 20% of annual gasoline is consumed during this period, but 33% of annual diesel consumption occurs over this period. This confirms the fact that heavy equipment with diesel engines is used more frequently during this time period for snow removal, resulting in higher fuel consumption and GHG emissions.

Table 1 Annual Fuel Consumption and GHG Emissions

	Units	Diesel	Gasoline
Jan 1 - Mar 15 Fuel Consumption	L	53,551	22,006
Percent total	%	33%	20%
Estimated Annual Fuel Consumption (L)	L	160,426	108,544
Annual GHG (kg CO2e)	kg CO2e	425,449	288,321
Annual Energy Consumption (MJ)	MJ	5,890,827	4,070,420

Figure 1 and Figure 2 below show the breakdown, in percent total fuel consumption, for each class of vehicle/equipment

.

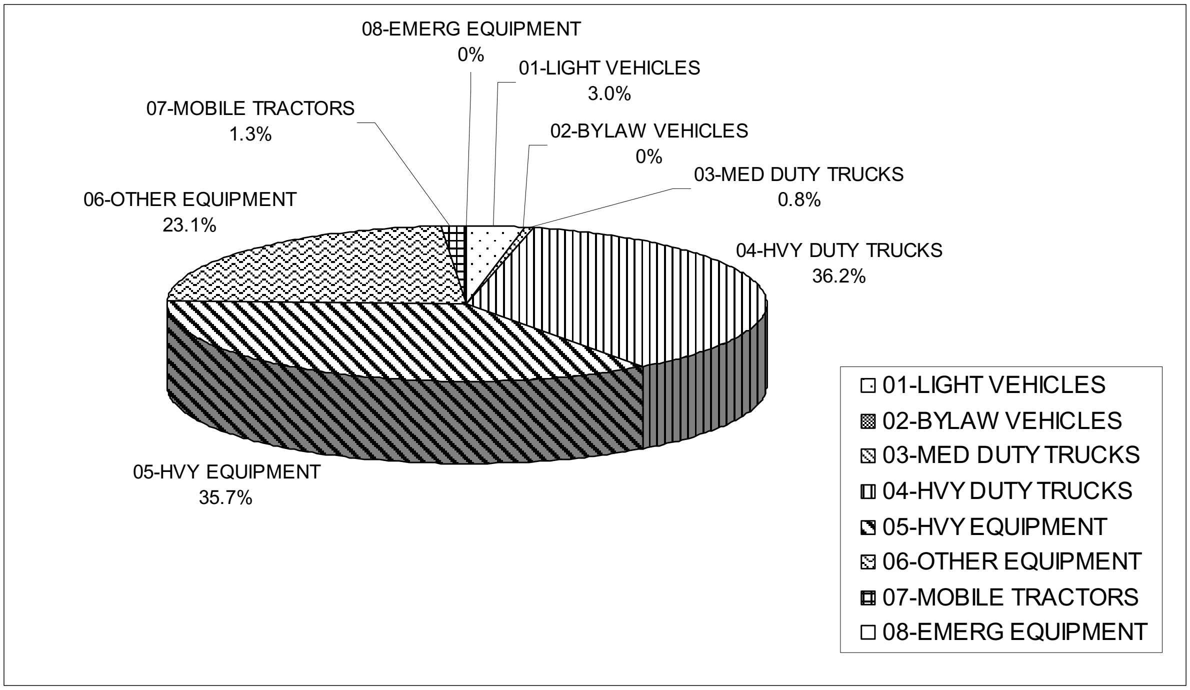

Figure 1 Percent total fuel consumption for diesel-powered vehicles/equipment

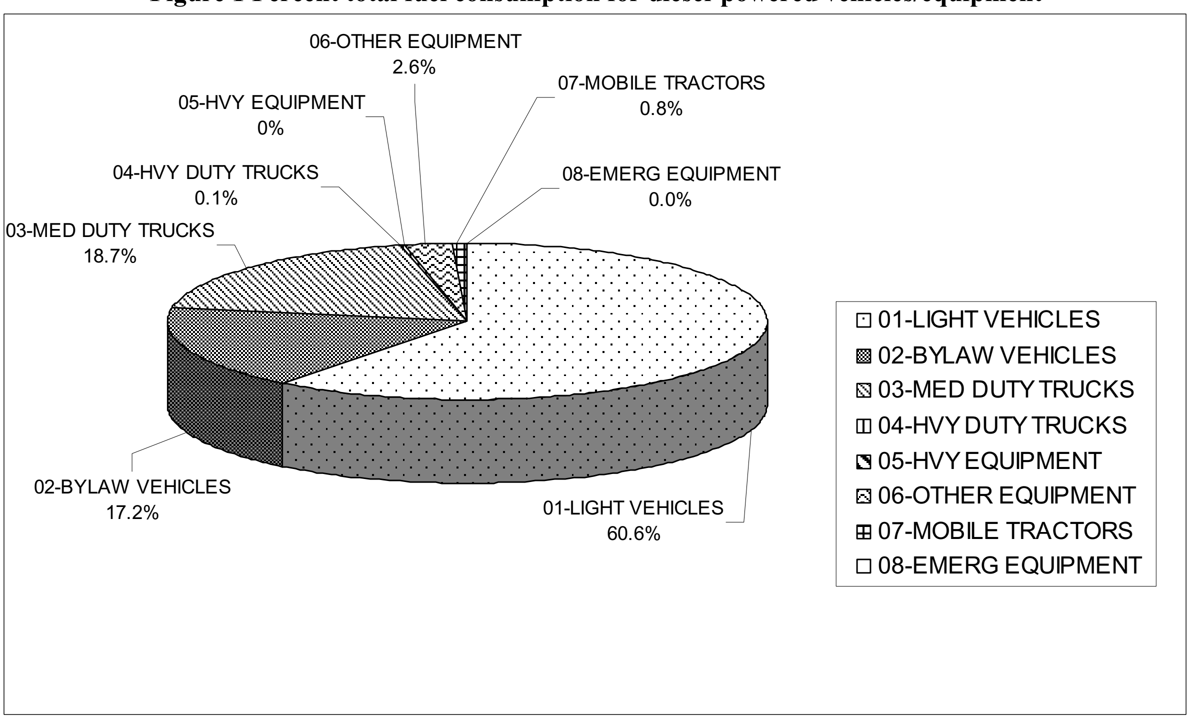

Figure 2 Percent total fuel consumption for gasoline-powered vehicles/equipment

From Figure 1 and Figure 2 it can be seen that heavy equipment, heavy duty trucks, and other equipment (generators, etc.) account for the largest percentages of diesel consumption. Passenger vehicles such as light vehicles, bylaw vehicles, and medium duty trucks account for the largest percentages of gasoline consumption. Based on this data, the following sections of the report explore options to realize gains in fuel efficiency for the City of Yellowknife's fleet.

2.3 Fuel Consumption and Greenhouse Gas Emissions from Water/Sewage operations

The areas of Old Town and Latham Island are isolated from the rest of Yellowknife in that they have no water and sewer mains that are operational year-round. Therefore, the city has contracted Bromley and Son Ltd. to supply Old Town with water from water trucks and Kavanaugh Brothers Ltd to remove sewage from the septic tanks with sewage vacuum trucks.

For water truck operations, fuel consumption data for the year of 2005 from Bromley and Son Ltd. showed that 54,000 L of diesel was consumed which resulted in 148,512 kg of CO_2 emissions. It should be noted that water trucks are not utilized in the summer months of June – September, as there is an un-insulated piped system that is used.

There was no fuel consumption data available from the sewage truck operations, but conversations with local Yellowknife residents have concluded that house hold water consumption leads to 1 water truck trip per 2 weeks, while sewage tanks have to be emptied typically every 3-4 weeks. Based on this information, as well as the fact that sewage trucks are run year-round whereas water trucks are run 9 months of the year, it is estimated that sewage truck operations result in a consumption of 37,333-49,778 L of diesel and 99,008-105,778 kg of CO_2 emissions.

Compared to the City of Yellowknife's total fleet fuel consumption of 160,426 L diesel annually, trucking water and sewage to/from Old Town and Latham Island is equivalent to 57-65% the total diesel consumption of the entire fleet. The City could consider developing infrastructure for Old Town and

Latham Island, and weigh the costs of infrastructure development against the costs of sub-contracting water truck and sewage truck providers.

3.0 Fleet Management Strategies

3.1 Case Study 1 – Whitehorse, YK

The City of Whitehorse, Yukon has implemented several methods to improve their fleet operations energy efficiency. Firstly, an anti-idling campaign was implemented in 2005 for all City department vehicles. The anti-idling campaign did not use any anti-idling technology. It only encouraged drivers to turn off their vehicle when not in use, stating that 10 seconds of warm-up is sufficient for vehicles before driving them. The public awareness portion of the anti-idling campaign was focused around posting signs, and broadcasting information such as idling statistics over the radio. Figure 3 below shows a fictitious character, "Auntie Idle" used in the campaign.

Figure 3 Cartoon character used in Yukon Anti-Idling Campaign for public awareness (image obtained from http://www.taiga.net/nce/antiidle/index.html)

During an interview with the City of Whitehorse's fleet maintenance manager George White, he found that the campaign was not as successful as hoped. According to Mr. White, the main reason behind the ineffectiveness of the campaign was that drivers are still idling their vehicles so they can stay warm and comfortable in the cold climate. The problem could be due to the anti-idling campaign itself, as it did not address issues with cold climates, and comfort, as most people were still idling their vehicles to remain warm during the winters.

Another method undertaken by the City of Whitehorse has also been the use of synthetic motor oil as part of their maintenance. Mr. White stated that they have used Shell brand synthetic motor oil for many years. Based on fuel consumption data, Mr. White has not noted any fuel savings when using synthetics as opposed to standard motor oil.

Another method to increase Whitehorse's fleet energy efficiency has been the adoption of a driver training program for the city's transit drivers similar to Edmonton's *Fuel Sense* program. The program teaches drivers how to drive fuel efficiently by using a closed-course route and a vehicle that has its fuel consumption monitored.

3.2 Case Study 2 – Anchorage, AK

The City of Anchorage, Alaska has been testing many different methods to increase the fuel efficiency of their fleet vehicles. The main focus of the city has been on using alternative fuels. Since 1995, the city has been using compressed natural gas (CNG) vehicles. These include vehicles that operate only on CNG and hybrid CNG-gasoline vehicles. In 1994 when they first started using CNG vehicles there was only one dedicated CNG car on the market, so they opted to modify their vehicles to use CNG and gasoline. The city found that having bi-fuel vehicles was not successful because once the vehicle ran out of CNG, the drivers would only fill up on gasoline and not bother filling up on CNG. Now, the City's Fleet has fifteen 2001 Honda Civic CNG cars running only on CNG. They only use these Honda Civics to transport people because they are limited by their size and the distance they travel from the fuelling station. The problems encountered with the bi-fuel vehicles could be a capacity issue. With proper driver training, the drivers would more frequently fuel up the vehicles with CNG.

When CNG vehicles were first used, there was only one fuelling station in all of Anchorage. Later, three fuelling stations were established but these cannot accommodate a larger demand. The City paid for the construction, operation, and maintenance of each CNG fueling station, as they are all located in the City's garage. Each fueling station represented approximately a $500,000 USD investment.

Recently, the city acquired two 2002 Honda Civic hybrid vehicles. According to Ron Collins, the Principal Administration Officer of the fleet maintenance department in Anchorage, the largest hurdle in implementing alternative fuel usage was that there is no infrastructure available.

Bio-diesel was also investigated by the city, but there were no distribution centers or refineries close to Anchorage so the costs involved were too expensive. The hybrid vehicles have been the greatest success so far. They have not needed any special maintenance and are operating very effectively.

Similar to Whitehorse, Anchorage has also implemented an anti-idling campaign. In 1994, the city purchased a few direct-fired heating systems to test out the technology. Unfortunately, the technology did not operate correctly and was later abandoned in 1995. Currently, the anti-idling campaign does not use any anti-idling technology and suggests users to turn off the vehicle's engine instead of idling. Just like in Whitehorse, the campaign has been ineffective because people want to stay warm and comfortable in their car. The main reason the anti-idling campaign failed was because of the cold climate. Most idling was done in police vehicles to run emergency gear/laptops/accessories. They also found that people were idling to keep the cab of the vehicle warm and that idling was a force of habit. People still idle because there is very little incentive for them to stop (there is no enforcement of the rules). The campaign did address the cold weather. They encouraged the use of block heaters to reduce idling. They also had electrical outlets installed outside to plug in the block heaters.

Anchorage's fleet has also explored using synthetic motor oils, but do not continue to use it because the costs have not shown an added benefit based on maintenance records and fuel consumption data.

4.0 Fuel-Efficient Vehicles

There are a number of fuel-efficient vehicles on the market, and there could be an opportunity to replace some of the City of Yellowknife's fleet of light vehicles, and bylaw vehicles with fuel-efficient vehicles. In most cases, fuel-efficient vehicles are more expensive than their counterparts, thus optimal fuel savings are found for frequent-use vehicles. For the City of Yellowknife, this would be most applicable to the bylaw vehicles, which are used with a high frequency, and typically travel over 30,000 km per year.

4.1 Hybrid Vehicles

Hybrid vehicles use small fuel-efficient engines coupled with electric motors to provide fuel efficient transportation, and high fuel efficiencies. Hybrid vehicles are equipped with advanced control systems, that recover power from regenerative braking, and the vehicles are equipped with fuel-efficient gearing ratios. Hybrids typically include periodic engine shutoff to save fuel and eliminate excessive idling. They are also equipped with advanced aerodynamics to reduce aerodynamic drag, and low-rolling resistance tires that effectively reduce drag on the pavement.

Sales of hybrid vehicles in the U.S. have increased dramatically in the past few years, as is shown below in Figure 4. Overall, they represent 1.2% of all vehicles sold in the U.S.A. in 2005. Conservative estimates state that hybrids will represent 3% of all vehicles sold in the U.S.A. by 2010, but given the recent dramatic escalation of fuel prices, it is now expected that hybrids will comprise between 5-6%.

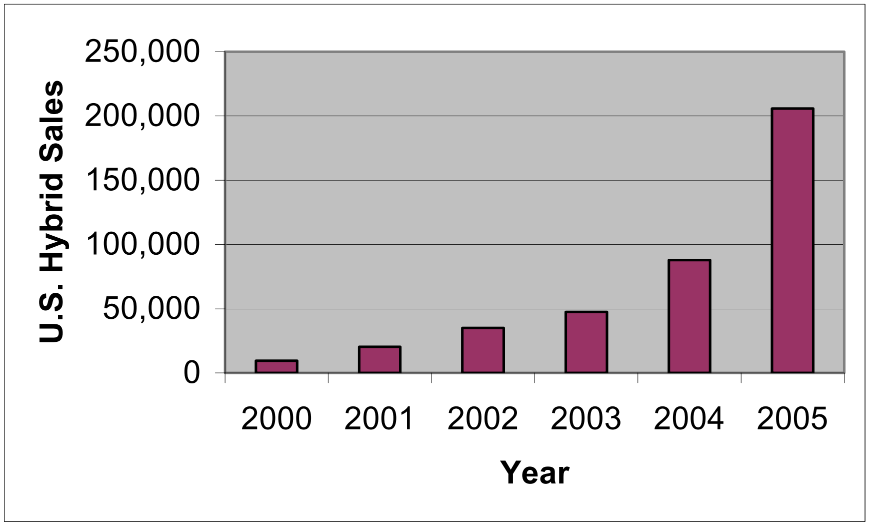

Figure 4 Hybrid Sales in the U.S.A.
(data obtained from http://www.hybridcars.com/sales-numbers.html)

The costs of hybrid vehicles are as follows (MSRP values): approximately $36,178 for the Honda Accord Hybrid, $25,858 for the Honda Civic Hybrid, and $25,356 for the Toyota Prius Hybrid. It should be noted that Autotec, based out of Yellowknife, is a licensed dealer of the Toyota Prius Hybrid vehicles, and is licensed to repair the Prius as well.

4.2 Smart Car

The *Smart Car* was initially popularized in Europe, where compact vehicles have been highly popular over the past decades. For many years, Europe has had higher gasoline and diesel prices than in North America, since fuel is heavily taxed (60% taxes in the EU). This has shifted many Europeans to seek small, fuel efficient vehicles. Selling features of the *Smart Car*, asides from its unique look are its extremely compact size and fuel economy (60 MPG).

Figure 5 *Smart Car Fourtwo* coupe
(image from http://en.wikipedia.org/wiki/Smart_(automobile))

The *Smart Car* was introduced to Canada, through Mercedes-Benz dealerships in 2004. In major urban areas, there have been long waiting lists, up to 6 months for the acquisition of these vehicles. There has been one *Smart Car* purchased by a Yellowknife resident. The owner has been contacted, and has reported that the vehicle has performed well, and it was used on a regular basis during the 2005-2006 winter in Yellowknife. No mechanical issues arose during or after the winter period, and the vehicle has received only minor work (ie. Oil changes, etc.). The MSRP of the *Smart Car FourTwo* is approximately $25,683.

4.3 Compressed Natural Gas Vehicles

Compressed natural gas (CNG) vehicles are cleaner burning than gasoline and diesel vehicles. Medium and heavy-duty CNG vehicles have shown to reduce over 90 percent carbon monoxide and particulate matter emissions and reduce emissions of nitrogen oxide by over 50 percent when compared to diesel engines. The CNG is stored onboard compressed gas cylinders pressurized between 3,000 and 3,600 psi. CNG vehicles generally have a shorter range than gasoline or diesel vehicles due to the lower energy content of natural gas.

There are currently only a few vehicle manufacturers that offer natural gas vehicles and as of 2006 manufacturers are producing fewer models than years past. These vehicles also vary depending on the type of CNG fuel system such as dedicated CNG or bi-fuel CNG. Dedicated CNG fuel systems can only run on CNG fuel whereas bi-fuel CNG systems can run on either gasoline or CNG due to two separate fuelling systems. The table below shows commercially available CNG vehicles. It has been found that dedicated CNG vehicles perform better and have lower emissions than bi-fuel vehicles because they have been optimized to run on natural gas.

Table 2 CNG Vehicles from Honda and General Motors in 2006

Company	Model	Vehicle Type	Fuel Type
Honda	Civic GX	Compact Sedan	Dedicated CNG
General Motors	Chevy Silverado 4x2	Light-duty pickup	Dedicated CNG or bi-fuel CNG
General Motors	GMC Sierra 4x2	Light-duty pickup	Dedicated CNG or bi-fuel CNG

Another method to acquire a CNG vehicle is to use an after-market conversion kit to convert a gasoline vehicle into a CNG vehicle. ECO Fuel Systems Inc. provides conversion kits that range in price depending on the vehicle. The MSRP of the Honda Civic GX cars is approximately $25,403.

4.4 Compressed-Air Vehicles

Moteur Developpement International Ltd (MDI) has developed a car with a Compressed Air Technology System (CATS) that uses compressed air as fuel. The pistons in the engine are powered by the expansion of the compressed air. The only exhaust from the car is 0ºC to -15ºC air. Therefore, zero-emissions are emitted to the atmosphere.

On-board compressed gas cylinders are used to store compressed air at 4350 psi. The air tanks are refilled by plugging the car into electricity sockets to start the motor-alternator which compresses ambient air. With a 230V socket, the MiniCATS take approximately 3.5 to 4 hours to refill. In the future, the company plans on having high pressure refilling stations that can refill a car in 3 minutes. The MiniCATS has an approximate range of 200 km.

There are two engines designed for different driving needs. The first is a single energy compressed air engine that is available in both MiniCATS and CityCATS. This engine is strictly for city use because at speeds up to 50 km/hr only compressed air is used. The second engine is a dual energy compressed air plus fuel engine. This engine can be used for city and highway driving. At speeds under 50 km/hr compressed air is used but when speeds over 50 km/hr are needed the engine switches to a fossil fuel.

The MiniCATS has available seating for 3 and cost approximately €6,860 in Europe, costing an equivalent $10,000 Canadian. The CityCATS have room for 5 passengers and cost approximately €9,460 ($13,400 Canadian). However, the air cars are currently not widely produced.

4.5 Fleet Fuel Consumption, GHG, and Financial Impact

The City of Yellowknife's fleet includes bylaw vehicles which are old enforcement vehicles that have been passed down from the Police Department. The fleet includes two Ford Crown Victoria vehicles and one Dodge Intrepid. These vehicles are operated heavily, and consume a total of 18,622 L of gasoline yearly. The Crown Victoria vehicles have poor fuel efficiency, at 17 MPG in the city. The Dodge Intrepid has higher fuel efficiency, 27 MPG in the city. The City of Yellowknife could potentially replace these vehicles with hybrids, and three popular hybrid vehicles were considered including: 2006 Honda Accord Hybrid, 2006 Honda Civic Hybrid, and the 2006 Toyota Prius Hybrid. In addition, *Smart Cars* and CNG vehicles would also be good candidates.

Based on available fuel consumption data, Table 3 shows the details of the cost to the City to replace the three bylaw vehicles with hybrids, *Smart Cars,* or *Honda Civic GX's.* .

Table 3 Financial, Energy, and GHG impacts of replacing bylaw vehicles with fuel efficient vehicles

Measure	Energy Impact		GHG Impact		Financial Impact	
	Fuel displaced (L)	Energy displaced (MJ)	kg CO2e	% reduction*	Capital Cost	Annual Savings
Replace all 3 bylaw vehicles with 3 Honda Accord Hybrid vehicle	3,476	130,354	9,233	19.1%	$108,534	$2,742
Replace all 3 bylaw vehicles with 3 Honda Civic Hybrid vehicles	10,895	408,545	28,939	59.7%	$77,574	$8,592
Replace all 3 bylaw vehicles with 3 Toyota Prius Hybrids	12,311	461,672	32,702	67.5%	$76,086	$9,710
Replace all 3 bylaw vehicles with 3 Smart Cars	13,037	488,897	34,630	71.5%	$77,049	$10,282
Replace all 3 bylaw vehicles with 3 Honda Civic GX Cars	6,789 GLE**	225,553	12,270	25.3%	$76,208	$3,652

* Figures presented as % reduction of GHG emissions for the fuel displaced

** GLE = gasoline liter equivalent

Hybrids could displace between approximately 3,500-12,300 L of gasoline annually, representing a GHG reduction of approximately 19%-68%. Replacement of the bylaw vehicles with *Smart Car*s would realize a saving of approximately 13,000 L of gasoline and GHG reduction of 72%. Also, using *Honda Civic GX* CNG cars would reduce 6,789 L of equivalent gasoline and reduce GHG emissions by 18%. However, there is no fueling infrastructure for CNG in Yellowknife, thus hybrids or *Smart Cars* would be the best options for the City of Yellowknife. Hybrid vehicles such as the Honda Civic Hybrid, and the *Smart Cars* are in fact slightly cheaper to purchase than the Police Interceptor model vehicles that are currently purchased, and they would see significant fuel savings over the Police Interceptors.

The City of Yellowknife's bylaw vehicles have a number of communications equipment that needs to fit inside of the bylaw vehicles, and there is a concern that such equipment cannot fit inside of a compact vehicle. However, other municipalities in Canada have used compact fuel-efficient vehicles for use as bylaw vehicles. As of April 2006, the City of Brampton, ON introduced 16 fuel-efficient vehicles (*Smart Cars* and hybrids) for use in fleet operations. The hybrids selected were the Honda Civic hybrid, and the municipality expects to save $13,000 in fuel costs. Figure 6 below shows the City of Brampton, ON and their recently purchased *Smart Car* vehicles.

Figure 6 Bylaw vehicles in the Brampton, ON city fleet
(Image from http://www.city.brampton.on.ca/press/06-057.tml)

As for communications equipment, the municipality of Brampton has made minor adjustments to fit the communications equipment inside the compact vehicles. Therefore, it is feasible for the City of Yellowknife to use fuel-efficient vehicles as bylaw vehicles. If the communications equipment still cannot fit inside of the compact vehicles, perhaps the communications equipment needs to be upgraded.

5.0 Equipment Maintenance

5.1 Tire Maintenance

A vehicle's rolling resistance is a major factor that affects fuel efficiency and rolling resistance is affected by tire pressure. According to the Rubber Association of Canada, every 2 psi of under inflation in a tire results in a 1 percent increase in fuel consumption. The temperature of the climate plays a role on tire pressure. Approximately, for every 5º C drop in temperature the tire pressure drops 1 psi. Also, tires are permeable so they can lose up to 2 psi a month. Although over inflating a tire reduces rolling resistance and lowers fuel consumption, a high tire pressure also results in a bumpier ride, potential increased wear of steering and suspension components, and reduced tire life. It is best to operate the tire at the inflation pressure shown on the vehicle information placard.

Proper tire maintenance not only increases fuel efficiency it also increases tire life. An increase in tire life also reduces costs because fewer tires are being replaced, and it also reduces the amount of GHG emission because according to the Rubber Association of Canada, the energy and material used in manufacturing four tires is equivalent to 26 litres of gasoline.

5.2 Preventative Maintenance

One aspect of preventative maintenance is car tune-ups. By keeping a car in tune, the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) have found that gas mileage improves by an average of 4 percent, but varies based on the kind of repair and how well it is done. Replacing a clogged air filter is another step in vehicle maintenance that increases fuel economy. The EPA and DOE have found that replacing a clogged air filter improves gas mileage up to 10 percent. They have also found that using the manufacturer's recommended grade of motor oil can improve gas mileage by 1 to 2 percent. When motor oil labeled "Energy Conserving" is used, Natural Resources Canada has found that there is a decrease of up to 2.7 percent in fuel consumption. This is due to the friction-reducing additives in energy conserving motor oil. Another step in vehicle maintenance to increase fuel economy is to maintain the vehicle's emission-control system. Modern vehicles have been equipped with an emission-control system to treat exhaust emissions. However, if the emission-control system is not inspected and maintained as suggested by the manufacturer's recommendations, the vehicle becomes a large polluter. Vehicles manufactured after 1996 have an on-board diagnostic system that monitors the emissions-control system. When a problem occurs with the emission-control system, a "Service Engine Soon" or "Check Engine" light alerts the driver. For vehicles manufactured before 1996, the emission-control system must be tested by a mechanic to ensure it is working correctly. According to British Columbia's AirCare program, fuel consumption improved by 15 percent when the emission-control system was repaired on faulty vehicles. This could be a consideration for the City of Yellowknife's fleet, as it includes 25 light duty vehicles that were manufactured prior to 1996.

5.3 Synthetic oils

Synthetic motor oil is an engineered lubricant made from chemical base stocks and additives unlike petroleum-based motor oil which is refined from crude oil. In petroleum-based motor oil some contaminants such as wax are difficult to remove from the oil. This wax can reduce the oils lubrication in cold temperatures. Synthetic motor oil does not contain contaminants so it actually begins lubricating at approximately -37º C rather than -28º C for petroleum motor oil.

There are many advantages to synthetic motor oils, but there are also disadvantages. The main disadvantage to synthetic motor oils is its expensive initial costs. AMSOIL's 100% synthetic 5W-30 motor oil (ASL) costs about $7.40/L, but when compared to Pennzoil's 5W-30 petroleum motor oil which cost about $3.17/L it is more than two times the cost. The cost of using synthetic oils could be offset if synthetic oils resulted in more mileage. However, research has shown mixed results. AMSOIL states that for light-duty non-turbocharged diesel engines and gasoline fleet vehicles using the 100% synthetic 5W-30 motor oil can extend oil drain intervals up to two times the manufacturer's suggested timeframe. Conversely, Rodgers et al. found that when synthetic motor oils were tested in five V-8 engine vehicles that the synthetic oils did not provide necessary performance required to safely recommend usage for extended oil change intervals. Another draw back to synthetic oils is that they do not reduce GHG emission levels when compared to petroleum motor oil as found by Lechner et al. They also found that synthetic motor oil did not reduce emission levels from a vehicle when compared to petroleum motor oil. It should be noted that these were studies done in the South, and although they may have shown mixed results with respect to synthetic oil impacts on fuel consumption, there is a sound argument that synthetics shall be used in Yellowknife, due to the lubricating abilities of synthetics under cold climates.

5.4 Driver Training Programs

The *Fuel Sense* program is a driver training program for the city of Edmonton's fleet operations drivers that combine defensive and fuel-efficient driving techniques. The program is also incorporated into Edmonton's transit driver training program. The driving techniques taught in the program focus on driver skill development and also helps remove poor energy efficient habits such as excessive idling and variable speed driving.

The *Fuel Sense* program was first implemented in March 2001 and is still on-going. The program was a direct response to the City of Edmonton's commitments to reducing emissions from City operations and reducing fleet operations costs. The *Fuel Sense* program's objectives were: (1) to achieve a 5 to 10 percent reduction in overall municipal fuel use in the program's first year, (2) to maintain fuel cost reductions through reduced consumption, (3) to reduce GHG emissions in the city and (4) to encourage a wider use of both *Fuel Sense* techniques and an improved defensive driver training program.

The *Fuel Sense* program consists of an initial four-hour training session and a re-test three months later. The drivers first attend a two-hour classroom session where they learn about GHG impacts on the environment and the climate, the potential cost saving associated with efficient driving techniques, and the correlation between speed, revolutions per minute (RPM), and fuel efficiency and excessive idling. Next, the drivers are taken for a two-hour on-road instruction session on a special closed street course. Here the drivers do a pre-test to establish a benchmark of their normal driving performance. Then the driver goes through the course again but with a trainer giving instructions. The vehicle driven during the test is also equipped with on-board computers that record RPM, speed, and fuel consumption. After the test, a driver is able to see the direct correlation between fuel efficiency, RPM, and speed. Three months later, the driver is re-tested to evaluate their retention of the *Fuel Sense* program.

In June 2004, the results of the *Fuel Sense* program were reviewed. Results indicated that fuel consumption savings of up to 15% overall will be consistent regardless of the type of vehicle. In addition, fuel consumption per kilometer dropped by approximately 5.5%, or a gain in fuel efficiency of 1.8 litres/100 km. The fuel savings per kilometer are achieved through optimizing driving techniques (acceleration, braking, etc.), while the other fuel gains to achieve 15% are through maintenance, reduction in idling, etc. It was also estimated that 350 tonnes of GHG emissions were avoided annually.

The first year start-up costs for the *Fuel Sense* program was $59,770. It is also estimated that the program annually costs $42,500. The costs are broken down and shown below in Table 4. These costs are for training 1,000 operators.

Table 4 *Fuel Sense* Program's First Year Start-up Costs and Annual Costs

	First Year Start-Up Costs	Annual Costs
Handbook Printing	$1,808	$2,000
Promotional Items	$6,720	-
Event Launch	$742	-
Development Staff	$10,000	-
Delivery Staff	$38,000	$38,000
Consumables (ie. Fuel)	$2,500	$2,500
Total	$59,770	$42,500

Although it may be more practical for select employees from the City of Yellowknife to be trained on the *Fuel Sense* program, the *Fuel Sense* training is only available to employees of the City of Edmonton. However, *Fuel Sense* has being adapted by the City in partnership with Natural Resources Canada's Office of Energy Efficiency (OEE) with an aim to develop an online training course. The program is named *FleetSmart* and the OEE. Materials are available online at <http://oee.nrcan.gc.ca/transportation/business/> and can be downloaded for free. The OEE also facilitates the delivery of *Smart Driver* training, which is administered through various trucking and fleet companies, and one can register through the OEE to receive updates as to when and where driver training programs are being held.

Thus, the options for the City of Yellowknife are a) to use the online resources from the OEE; or b) develop its own program based on *Fuel Sense*, much like the City of Whitehorse. However, the first option is much more economical, and supervisors from the City of Yellowknife could distribute such materials to employees of the City of Yellowknife and users of the fleet.

5.6 Fleet Fuel Consumption, GHG, and Financial Impact

Tire maintenance, preventative maintenance, and use of synthetic oils are most applicable to the City's fleet of the following vehicles:

- Light vehicles

- Bylaw vehicles
- Medium duty trucks
- Heavy duty trucks
- Wheeled heavy equipment

The applicability of driver training programs is most applicable to only light vehicles, bylaw vehicles, and medium duty trucks.

Table 5 below shows the details of implementing such controls and programs and applying them to the City of Yellowknife's fleet of utility/work vehicles. The measures identified below require no additional infrastructure, although some additional funding would be required for establishing a preventative maintenance program, purchasing all-synthetic motor oil, and implementing a driver training program.

The *Fuel Sense* program includes maintenance issues in its training, thus the fuel efficiency gains quoted by the City of Edmonton for the *Fuel Sense* program adoption likely include fuel efficiency gains from tires, maintenance, etc. Thus, the maximum fuel efficiency gains expected would be 15% overall. It is not expected that maintenance alone would see significant gains in fuel consumption, as it is unlikely that the City's fleet is poorly maintained.

Table 5 Financial, Energy, and GHG impact of maintenance and training programs

Measure	Energy Impact		GHG Impact		Financial Impact	
	Diesel displaced (L)	Gasoline displaced (L)	kg CO2e	% reduction*	Cost	Annual Savings
Tire Maintenance	1,049	1,045	5,559	1.0%	negligible	$1,656.99
Preventative Maintenance	5,246	5,227	27,797	5.0%		$8,284.94
Energy-Conserving Motor Oil	2,833	2,821	15,006	2.7%	twice the cost of regular motor oil	$4,472.51
Driver Training	0	15,661	41,600	15.0%	Negligible costs for use of online resources, $60,000 start up, $42,500 per year afterwards for implementing a formal training program	$12,351.84

* Figures presented as % reduction of GHG emissions for the fuel displaced

6.0 Idling

6.1 Anti-Idling Campaigns

Anti-idling campaigns are focused on increasing public awareness with respect to idling. Many fleet vehicles idle 20-60% of the time, mainly out of driver habit rather than for operation and necessity. No more than 30 seconds of start-up idling is necessary to warm up the oil inside of a vehicle in the winter, and the best way to warm a vehicle is to drive it. Typically Anti-idling campaigns recommend the following advice, usually posted on websites and advertised over the radio.

- Minimize warm-up idling, and only idle for 30 seconds, as long as windows are clear
- Use a block heater, with automatic timer for 2 hours heating prior to driving vehicle
- Turn off engine after 10 seconds of idling
- Avoid remote car starters
- Use synthetic motor oils

In addition, signs are typically posted stating "Idle-Free Zone" or equivalent. As of May 2, 2005, Burlington ON passed an anti-idling bylaw. Maximum of 3 minutes with some exceptions, and then proponents are issued fines by bylaw officers. Idling is permitted when temperatures fall below 5 degrees or climb above 27 degrees <http://www.climatechange.gc.ca/onetonne/english/antiidle.asp>. Exceptions are also made for emergency vehicles, and equipment (garbage trucks, etc.). Vehicles activated by remote starters are also subjected to bylaw. The City of Whitehorse unanimously rejected the adoption of a similar anti-idling bylaw on January 12, 2004.

Many anti-idling campaigns in cold climates have failed, or seen limited success, due to the fact that drivers want to remain warm in their cars. Anti-idling technologies have emerged, which can tackle this obstacle which has hindered past anti-idling campaigns in cold climates.

Unlike gasoline fuel injected engines, diesel engines may need to be idled to avoid start-up problems. Diesel engines become difficult to start when temperatures are below diesel's solidification temperature. The solidification temperature is set by the fuel producer based on the type of climate the fuel is used in. When temperatures reach the solidification temperature, a solid called paraffin forms in the fuel.

Although paraffin will not block the fuel pump, the fuel filter may get blocked and the vehicle may not start as a result. Idling the vehicle, and in-turn keeping the diesel fuel warm, reduces this start-up problem. This is most applicable to heavy equipment and heavy duty trucks, where idling in cold climates is the norm on construction sites. In addition, since most construction sites do not have easy access to electricity, and generator sets are required for electrical power generation. This makes it more difficult to plug in block heaters overnight, as the generator sets must be left unattended.

6.2 Anti-Idling Technologies

Anti-idling technologies use a fraction of the fuel of idling a vehicle. The fuel is burned in a direct-fired heater to provide heating for the engine block. Some systems use battery power to provide electricity for the interior of the vehicle. At idle, light passenger vehicles consume between 0.8-1 L/h of fuel. Pickup trucks consume approximately 1.6 L/h of fuel at idle (Ackelik and Besley, 2003). Heavy equipment consumes in the order of 3.5 L/h.

6.2.1 Direct-Fired Heating Systems

The *BlueHeat* Coolant Heater by Webasto is a device that provides engine pre-heating and cab heating without idling the car engine. The *BlueHeat* uses the vehicle's battery and fuel (either gasoline or diesel) to power the system. Fuel is burned in a direct-fired heater to provide heating to the engine. Once the vehicle's fuel is burned in the *BlueHeat* system, engine coolant is circulated through the system to pickup the heat. The coolant is then used to transfer heat to the vehicle's cab and to the engine. Because the *BlueHeat* system operates off the vehicle's battery, the vehicle's engine must be operated from time to time to recharge the battery.

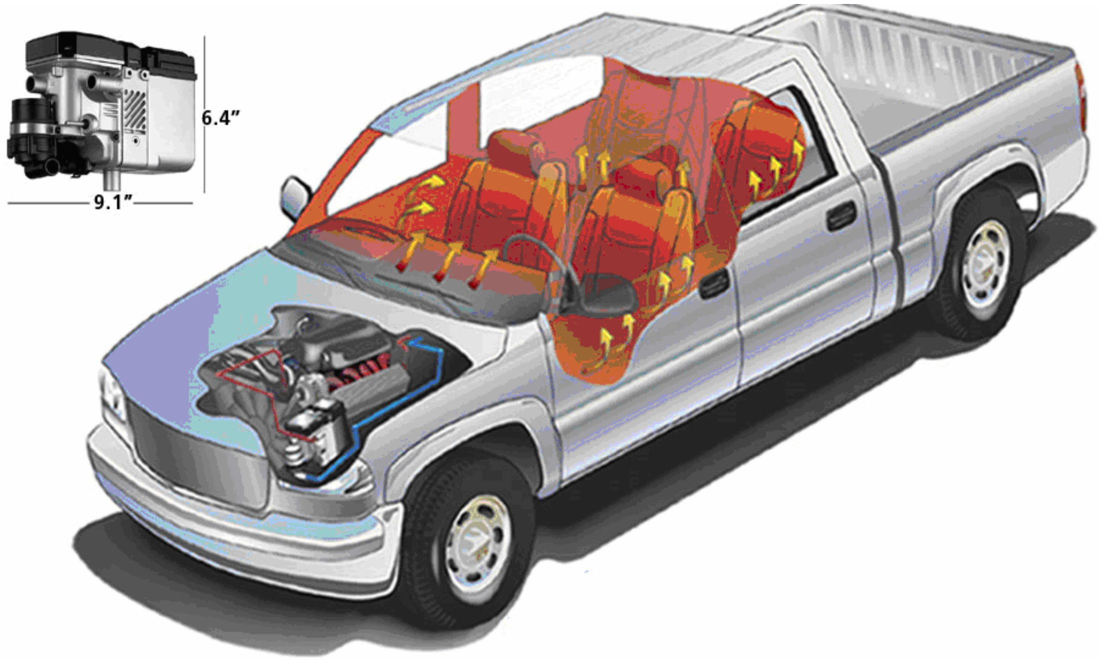

Figure 7 *BlueHeat* system
(image from http://www.webastoshowroom.com/blueheat/thermo_truck-4.htm)

There are two heating setting for the *BlueHeat* system. The full heating setting produces up to 5 kW of heat and consumes approximately 0.61 L/hr of fuel. Whereas the reduced heating setting produces 2.5 kW of heat and consumes approximately 0.30 L/hr of fuel. The *BlueHeat* system is relatively small, weighing 7 pounds and depending on the vehicle can be installed underneath the hood or along the frame of the vehicle. The units are also compact, with dimensions of 9''x4''x7''. A dash-mounted digital timer can be programmed to automatically start the system or a remote control can be used to manually start the system. Because of their operational efficiency, these units can offer an alternative to remote starting a car's engine in cold weather.

As far as applicability to the City's fleet of vehicles, the *BlueHeat* unit is available for Ford F-series vehicles, and it could be fitted on any of the City's F-150, F-250, and F-350 vehicles. However, it should be noted that similar systems exist, and are available for almost any type of passenger vehicle, but for this study due to the prevalence of F-series vehicles within the City's fleet, the Webasto system was considered for calculation purposes.

6.2.2 Battery Powered Heating Systems

The *Autotherm ERS* is a device that uses the vehicle's heater to heat the cab while the engine is turned off. In all cars, excess engine heat is carried away by cooling water that surrounds the engine. This heat is also used by the heater to heat the car cab. When the engine is turned off the cooling water to the engine stops flowing and the heater stops working. The ERS supplies heat by continuing to circulate coolant to the engine when the engine is turned off. The ERS only operates the coolant pump and the fan system; both of which are powered by the car battery. Therefore, no fuel is burned when using the ERS and consequently no emissions are produced. The ERS automatically turns on when the ignition key is turned off. Once the cooling water is less than 35º C the ERS automatically turns off because the water does not have enough energy for effective heating. The ERS also includes a voltage sensor that automatically shuts down the system before draining the battery so the engine can be restarted. The ERS system costs $539 Cdn. and only weighs 2.5 pounds.

The three main factors that affect the heating time provided by the *Autotherm ERS* are the designed operating temperature of the cooling system, the coolant capacity of the vehicle, and the outdoor temperature. The operating temperature of the cooling system defines how much heat is stored in the coolant. A higher operating temperature will store and supply more heat. Similarly, the amount of coolant also determines how much heat is stored and supplied. The outdoor temperature affects how quickly the heat is dissipated.

The drawbacks to the *Autotherm ERS* are that it does not pre-heat the engine and only operates correctly if the engine has been running for a period of time. Since it does not provide engine heating, direct-fired heaters would be a much more suitable anti-idling technology as opposed to battery-powered heating systems such as the *ERS* system.

6.2.3 Auxiliary Power Units (APU)

An auxiliary power unit (APU) is a device that is externally mounted to a truck to provide heating, air-conditioning, and power without idling. An APU usually consists of a small internal combustion engine, an air-conditioning compressor, and an alternator. The APU is a proven technology and is widely available.

When fuel is burned in a vehicle's engine, most of the energy goes to overcome friction and provide mechanical energy to move the vehicle. Only a fraction of the energy is supplied to the vehicle's heating system. The small combustion engine in the APU is sized to provide power to the air-conditioning compressor, and heat to the heater. The APU supplies heat by transferring heat from the small combustion engine to the vehicle's engine coolant. The engine coolant then transfers heat to the vehicle's cab and the engine. The alternator in the APU keeps the vehicle's batteries charged so electrical equipment can be used in the cab without starting the engine.

An APU is generally used in tractor trucks because of the large size and weight of the unit. One APU called the *Pony Pack* weighs about 300 pounds and is about 24 inches long by 26 inches tall by 27 inches deep. The Pony Pack retails as $6,500 US FOB Albuquerque, NM. However, some of the APU's will need to be modified and more information (such as available space, present HVAC system, and vehicle model year) about each vehicle is required before a more detailed price can be determined.

Figure 8 *Pony Pack* APU unit (www.ponypack.com/products.htm)

Conversations with the vendor have concluded that the *Pony Pack* can be retrofitted onto conventional heavy duty trucks such as tandem trucks, water trucks, etc. After consultation with Rex Greer, the president of *Pony Pack*, it was decided that the *Pony Pack* may be used in the following pieces of equipment:

- CAT 140G Grader
- CAT 214 Backhoe
- CAT 938G Loader
- CAT 950E Loader
- Ford Aeromax L9000 Tandem
- Ford LN8000
- Ford LT9000
- Freightliner FC70 Sweeper
- IHC Tandem
- Sterling Tandem
- Sterling Vac Truck

From the fuel consumption data, the Sterling Vac Truck appears to be the most active piece of heavy equipment in the fleet, consuming approximately 21,113 L diesel per year. The CAT 140G grader is the next highest at 13,157 L diesel per year, followed by the CAT 938G loader which consumes 11,730 L diesel per year. If these pieces of equipment are left idling consistently during the winter, they would be good candidates for installation of the *Pony Pack* APU unit.

6.2.4 Fuel Cell APU Systems

Research has found that fuel cells may be used in the future to power an APU. There are currently two types of fuel cells being investigated: polymer electrolyte membrane (PEM) fuel cells, and solid oxide fuel cells (SOFC). A PEM fuel cell is ideal because it produces zero GHG emissions. However, it requires high purity hydrogen as a fuel. A SOFC uses conventional fuels such as diesel, gasoline, propane, or natural gas, but because of this they still emit GHG emissions. The benefit to all fuel cell APU systems is that they provide cogeneration of power and heat. However, fuel cells are not a proven technology and are very expensive. These systems are still in the developmental stages and are not yet available on the market.

6.3 Fleet Fuel Consumption, GHG, and Financial Impact

To estimate the fuel savings for each anti-idling technology, an assumption of idling was made. It was assumed that 10% of the fuel consumption for each vehicle and piece of equipment considered was due to idling. Data from southern studies has shown that idling accounts for 6-8% of total fuel consumption, however idling is more frequent and prolonged in the winter in Yellowknife, therefore 10% is a reasonable estimate. Table 6 below shows the impacts of installing *BlueHeat* systems on the City's fleet of Ford F-series vehicles, as well as select heavy duty trucks and heavy equipment. Based the fuel prices of $0.79/L for gasoline, and $0.79/L for diesel (average fuel prices for the City), it is seen that the anti-idling technologies achieve simple paybacks of 18 years for the APU units, and 25 years for the *BlueHeat* units. However, with rising fuel costs, the payback periods could decrease significantly if fuel prices continue to rise.

If the City were to implement anti-idling technologies, it would be best to purchase one or two direct-fired heaters for pickup trucks, and one *Pony Pack* for a selected piece of heavy equipment, and monitor the performance of the unit by comparing fuel consumption data before and after installation. If the units meet or exceed the predicted outcomes outlined in Table 6, or if fuel prices continue to rise, the City could expand the use of such anti-idling technologies.

Table 6 Financial, Energy, and GHG impact of direct-fired heaters

Measure	Energy Impact		GHG Impact		Financial Impact	
	Diesel displaced (L)	Gasoline displaced (L)	kg CO2e	% reduction*	Capital Cost	Annual Savings
Install Blue Heat fired heaters in F-150, F-250, F-350 trucks	0	3,617	12,491	6.3%	$2282 each, $70,750 total for 31 unit installations	$2,852.93
Install APU units on heavy duty trucks	4,196	0	11,127	7.4%	$8055 each, $69,811 for 8 unit installations	$3,328.86
Install APU on heavy equipment	4,255	0	11,284	7.4%	$8055 each, $52,358 for 6 unit installations	$3,375.75

* Figures presented as % reduction of GHG emissions for the fuel displaced

7.0 Renewable Fuels

7.1 Bio-Diesel

Bio-diesel is a renewable alternative fuel made from vegetable oils, animal fats, or used cooking oils. There are many benefits presented by bio-diesel such as: a decreased dependence on imported fossil fuels, a reduction in waste cooking oil in the city dump, and ease of use. Currently, bio-diesel is readily available in the United States and Europe, where legislation has led to a demand for production of renewable fuels for use in automobiles, machinery, and furnaces. However, bio-diesel is not widely available in Canada. Bio-diesel easily blends with petro-diesel and can be found as B5 (5 percent bio-diesel and 95 percent diesel), B20, or B100. There is no separation between bio-diesel and petro-diesel once they are blended.

The American Society of Testing and Materials (ASTM) has quantified that any bio-diesel to be used in a compression-ignition diesel engine must meet the specifications set in ASTM Standard D6751. The simple process to produce bio-diesel from used cooking oil has led to many do-it-yourself "home-brewers" of bio-diesel. These home-brew bio-diesel plants do not use the sophisticated technology required to purify the bio-diesel to ASTM standards. One such system is the $2,995 *FuelMeister* from Bio-diesel Solutions. This system produces approximately 400 liters of bio-diesel per week and should be viewed as making "crude" bio-diesel because very little separation techniques are used to purify the bio-diesel. Overall the bio-diesel process is 70% efficient therefore if 100 L of waste oil are used, 70 L of petro-diesel will be produced, and 30% waste comprised of glycerol and soap is produced. The wastes must be disposed of separately; the glycerol can be incinerated, and the soap must be sent off to a landfill or waste management facility. Table 7 below shows a breakdown of approximate costs for various production systems.

Table 7 Estimated Costs of Various Bio-Diesel Production Systems

System	Production Capacity (L/week)	Capital Cost	Production Cost ($/week)	Cost Per Liter
FuelMeister	400	$2,995	$424	$1.06
Non-ASTM	1,000	$69,100	$1,081	$1.08
ASTM	3,000	$296,108	$2,320	$0.77

A very important aspect of bio-diesel is that in cold temperatures the fuel begins to gel at a higher temperature than petro-diesel. Under the extreme cold of winters in Yellowknife, this could pose problems with respect to clogged fuel filters and fuel injectors. B5 (5% bio-diesel) blends have shown to perform well under extreme cold conditions of -30C to -40C, comparable to winters experienced in Yellowknife.

In addition, bio-diesel is not compatible with all materials. Hoses and gaskets made out of rubber compounds such as natural rubber, nitrile, and Tygon have been known to soften and degrade when in contact with bio-diesel. Other materials such as Viton are chemically compatible with bio-diesel. Therefore, before bio-diesel is used in a system the user should contact the equipment manufacturer to verify material compatibilities.

When combusted, bio-diesel produces approximately the same amount of GHG emissions as petro-diesel. However, the life cycle GHG emissions are dramatically reduced when bio-diesel is used. While petro-diesel is produced from non-renewable resources, bio-diesel is produced from a renewable resource – plants that uptake CO_2 are eventually converted to cooking oil, and then bio-diesel. The DOE has found that substituting bio-diesel for petroleum diesel reduces life-cycle carbon dioxide emissions by 78 percent.

Based on the data that Yellowknife's city fleet consumes 160,426 liters of diesel yearly, a B5 blend would require approximately 8,000 liters of biodiesel a year. There are currently no suppliers or distributors of biodiesel in the Northwest Territories. Therefore, there are only two methods to obtain biodiesel to Yellowknife: (1) ship biodiesel to Yellowknife from somewhere within Canada, and (2) build a biodiesel production plant in Yellowknife. The first and largest biodiesel supplier in Western Canada is Canadian Bioenergy. They have supplied biodiesel to city fleets in Calgary and Vancouver since 2004. Canadian Bioenergy estimates that it would cost $11,754.59 (includes shipping, totes, GST, all provincial fuel taxes, and federal taxes) to ship 8,000 liters of biodiesel (or $1.469 per liter) from their distribution centre in Calgary to Yellowknife in eight 1,000 liter totes. A breakdown of the costs is shown below in Table 8.

Table 8 Estimated Costs for Bio-Diesel (B100) from *Canadian Bioenergy*

Item	Quantity	Unit Price	Total Cost
ASTM Biodiesel (B100)	8,000 L	0.8307 $/L	$6,645.60
1,000 L Tote	8	$130.00	$1,040.00
Shipping	-	-	$3,300.00
		Subtotal	$10,985.60
		GST	$768.99
		Total	$11,754.59

7.2 Ethanol blended gasoline

Ethanol is a renewable fuel made from plants such as corn, and wheat. It can be easily blended with gasoline and is commercially available in the United States and Canada. All ethanol-gasoline blends sold in Canada are E10 (a blend of 10 percent ethanol and 90 percent gasoline). In the United States, E10 and E85 are available. However, not all vehicles can operate on ethanol. Most vehicles manufacture after 1980 can use E10 without any modifications. A vehicle’s warranty may become void if ethanol blends higher than E10 are used. This is due to ethanol’s ability to break down zinc, aluminum, certain plastics, and rubbers. Ethanol also acts like a solvent, so any deposits in the fuel tank and fuel lines will be dissolved and deposited in the fuel filter. Recently, Flexible Fuel Vehicles (FFVs) have been manufactured by GM, Chrysler, Ford and many others. These vehicles contain stainless steel fuel tanks and fuel lines which ethanol cannot corrode. Also, these FFVs are capable of using straight gasoline or ethanol blends of up to 85 percent.

The effects of ethanol on GHG emissions and tailpipe emissions show a positive influence on the environment. Although carbon dioxide is still produced during the process of converting plants to ethanol and the combustion of ethanol, these GHG emissions are offset by the carbon dioxide absorbed during the growth of the next batch of plants used to produce ethanol. Therefore ethanol helps reduce GHG emissions because it produces zero net carbon dioxide. The amount of carbon dioxide reduced depends on the feedstock and energy source used to make ethanol. In Canada, natural gas powered production plants are used to convert corn and wheat to ethanol. The use of natural gas during this process creates carbon dioxide and ultimately decreases the overall reduction of GHG emissions by ethanol. When the entire process of making ethanol is taken into consideration, it has been found that E10 made from corn produces approximately 3 to 4 percent fewer GHG emissions than gasoline.

Ethanol also has effects on other types of vehicle emissions such as SOx, NOx, carbon monoxide, and volatile organic compounds (VOCs). Unlike gasoline, ethanol essentially contains zero sulphur because it is produced from plants. Therefore, ethanol contributes no sulphur emissions. A study in Alaska done by Knapp et al showed that when E10 was used in -28.9º C climate, carbon monoxide emissions decreased. However, this same study found that NOx emissions increased when compared to straight gasoline. VOCs such as benzene, 1-3 butadiene, toluene, and xylene are reduced when ethanol blends are used instead of gasoline. However, aldehyde emissions were found to increase but most aldehyde emissions are handled by a vehicles catalytic converter.

The effect of ethanol on a vehicles fuel economy has shown mixed results. Theoretically, ethanol fuels should have lower fuel economy than gasoline because ethanol has a lower energy value. However, research has shown that some vehicles fuelled with E10 showed slight increases in fuel economy. This has been attributed to the high oxygen content in ethanol which helps complete the combustion of the fuel leading to higher engine efficiency.

7.3 Fleet Fuel Consumption, GHG, and Financial Impact

Based on the above information, it can be determined that while producing bio-diesel would result in a lower cost per litre of fuel, Yellowknife simply does not have the quantity to supply an 1000 L/week, or 3000 L/week bio-diesel production system. Thus, it would be most feasible to truck in totes of bio-diesel to supply a B5 blend.

To supply 8,000 L bio-diesel per year, the approximate cost would be $1.47/L as opposed to the current cost of diesel which is $0.79/L. This would cost $11,920 per year to purchase the 8,000 L of bio-diesel as opposed to $6,347 per year to purchase petro-diesel resulting in an overall increase in cost of $5,573 per year. Although local GHG emissions would not be reduced, life cycle GHG reductions of 78% would be achieved within the diesel displaced by bio-diesel. In essence, a 3.9% reduction of GHG emissions would be realized for the 8,000 L of fuel displaced, resulting in a 2.3% overall fleet-wide reduction of GHG emissions.

Bio-diesel could be used to raise awareness with respect to renewable fuels, as the increase in cost is not a large quantity. As fuel prices continue to escalate, it is feasible that within a few years time, petro-diesel prices will rise above $1.47/L making bio-diesel feasible.

8.0 Conclusions

Using fuel consumption data obtained from the City of Yellowknife's Works Superintendent, it is estimated that the City's fleet consumes approximately 160,426 L of diesel and 108,544 L of gasoline annually. This results in GHG emissions of 425,449 kg CO_{2e} and 288,321 kg CO_{2e} respectively. A number of options were explored to reduce fuel consumption, and therefore GHG emissions.

By replacing bylaw vehicles with fuel efficient vehicles, it was found that compact hybrids (Honda Civic, Toyota Prius hybrids) and *Smart Cars* would be the most effective. With significantly higher fuel efficiencies than the bylaw vehicles that are currently being used, simple paybacks of 7-9 years would be achieved, based on current fuel prices. This would result in overall fleet decreases of 28,939-34,630 kg CO_{2e} (4.1-4.9% of total fleet emissions). Other municipalities have successfully implemented the use of compact fuel-efficient vehicles for use as bylaw vehicles, as has been seen by the City of Brampton, ON.

With respect to maintenance and driver training programs, it was found that driver training programs modeled around the City of Edmonton's *Fuel Sense* program would be the most effective, and could achieve efficiency gains of up to 15% for the vehicles operated. This would amount to an overall fleet decrease of 41,600 kg CO_{2e} (5.8% of total fleet emissions). The driver training could be achieved by a) implementing a program in Yellowknife, or b) taking online training courses developed by the Natural Resources Canada OEE. While the latter would be free, the former would require an initial start-up investment of $60,000, with subsequent operational costs being essentially the salary of one employee per year to maintain the program. If the start-up capital were raised, to purchase or retro-fit vehicles with sensors, and the program maintenance could be done by existing City employees, the simple payback on the investment would be less than 4 years. Another possibility would be if the City of Yellowknife could reach an agreement with the City of Edmonton for their *Fuel Sense* trainers to provide training in Edmonton for certain employees from the City of Yellowknife. However, at present the City of Edmonton only offers the training course to its own employees.

It was found that most anti-idling campaigns in cold climates have failed, due to driver behaviour, as drivers prefer to stay warm in their cars. Although further education and public outreach could correct this behaviour, anti-idling technologies were explored. These technologies would be especially applicable for heavy duty diesel equipment, where idling is at times a necessity in construction sites. Direct-fired heaters installed on every Ford F-series vehicle in the City's fleet would require an investment of \$70,750, producing a simple payback of over 25 years, which would not be feasible. It would, result in a GHG reduction of 12,498 kg CO_{2e} (1.8% of total fleet emissions). Installing APU units on heavy equipment would be more feasible. It would require an investment in the order of \$122,169 for 14 installations, resulting in a simple payback of 18 years, and a GHG reduction of 22,412 kg CO_{2e} (3.2% of total fleet emissions). However, with current escalation of fuel prices, the simple payback for both could decrease dramatically in the future. These anti-idling technologies are proven technologies and could be implemented slowly within the City's fleet, and performance could be monitored. They would be most applicable to vehicles and equipment that are heavily idled.

Finally, renewable fuels were discussed, and it was found that it would be unfeasible to build a bio-diesel facility in Yellowknife, and that bio-diesel would be feasible only if petro-diesel prices rise over \$1.47/L, as that is the current price of trucking bio-diesel to Yellowknife to supply a 5% blend of bio-diesel across the entire fleet. However, a slight increase in cost in purchasing bio-diesel of \$5,573 per year would result in an overall decrease of 2.3% of GHG emissions. Bio-diesel could be stored in totes provided by the supplier (Canadian Bioenergy Corporation), and could be mixed into the regular diesel fuel tanks.

If all of the measures identified in this report were implemented, an overall decrease in GHG emissions of approximately 15% would be seen. The most effective options to reduce the City's GHG emissions are prioritized in the following order:

1. A driver training program similar to the City of Edmonton's *Fuel Sense* program should be implemented first because it will have the greatest impact on fleet GHG emissions and the lowest economical impact. Online materials could be used, and supervisors could attend training sessions down south to cut costs.
2. Replacing the current bylaw vehicles with fuel efficient vehicles such as hybrids or *Smart Cars* should be explored second because this will have the second largest impact on GHG emissions and a low economical impact.

3. An anti-idling campaign to education drivers about idling impacts on vehicles and the environment should be implemented in conjunction with performance monitoring of a few direct-fired heaters and APU's installed on the most heavily used vehicles.

9.0 References

A Website by the Northern Climate Exchange "Yukon Anti-Idling Campaign" <http://www.taiga.net/nce/antiidle/index.html>, Accessed March 2006

A Website from hybridcars.com "Sales Numbers and Forecasts for Hybrid Vehicles" <http://www.hybridcars.com/sales-numbers.html>, Accessed March 2006,

Article, "Little Blue Cars Help Keep Brampton Clean and Green" <http://www.city.brampton.on.ca/press/06-057.tml>

News Article, "Whitehorse council rejects idling bylaw" <http://www.cbc.ca/north/story/jan13idling13012004.html>, Accessed March 2006

Transport Canada, Urban Transportation Showcase Program "Fuel Sense: Making Fleet and Transit Operations More Efficient" <http://www.tc.gc.ca/programs/environment/UTSP/fuelsense.htm>, Accessed March 2006

A Website by the EPA and the DOE, "Keeping Your Car in Shape" <http://www.fueleconomy.gov/feg/maintain.shtml> 2006

Natural Resources Canada "A Guide to AutoSmart Vehicle Maintenance: Read the Owner's Manual" <http://oee.nrcan.gc.ca/transportation/personal/maintaining/autosmart-car-care.cfm?attr=8#oil> 2005

Rodgers, John J. and Kabel, Richard H. Technical Paper "Vehicle Evaluation of Synthetic and Conventional Engine Oils", 1975

Manufacturer Website "Webasto *BlueHeat*" <http://www.webastoshowroom.com/blueheat/> Accessed March 2006

Manufacturer Website "The Pony Pack Unit" <http://www.ponypack.com/products.htm> Accessed March 2006

Centre for Transportation Research, Argonne National Laboratory, "Analysis of Technology Options to Reduce the Fuel Consumption of Idling Trucks", 2000

Akcelic, Rahmi, and Mark Besley. Technical Paper "Operating cost, fuel consumption, and emission models in aaSIDRA and aaMOTION", 2003, 25th Conference of Australian Institutes of Transport Research (CAITR 2003)

University of California, Davis Institute of Transportation Studies, "Evaluation of Fuel Cell Auxiliary Power Units for Heavy-Duty Diesel Trucks", 2002

News Article "Gas Prices too High?" <http://www.csmonitor.com/2005/0826/p01s03-woeu.html> 2005

Knapp, K. T., Stump, F. D., and Tejada, S. B. Technical Paper "The Effect of Ethanol Fuel on the Emissions of Vehicles over a Wide Range of Temperatures", 1998