An Assessment of Propane As a Transportation Fuel For Light-Duty Fleets in Canada

Preliminary Report

by Professor Gerald R. Higgins

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About the Author

Professor Higgins has taught Strategic Management and Finance at the graduate and undergraduate levels at the University of Western Ontario since 1980. During this period, he has also taught courses for the Canadian Institute of Management, the Canadian Insurance Institute, and the Institute of Canadian Bankers. He has led major strategic planning activities for such organizations as the Royal Bank of Canada, General Motors Canada, Westinghouse Canada, IBM, and the governments of Canada, Puerto Rico, Italy and Kenya.

Professor Higgins served as Senior Economic Advisor to the Honourable Tom Hockin, Federal Minister of Science & Minister of State for both small business and tourism from 1991 to 1992. These portfolios controlled such Federal Departments as the National Research Council, the Canadian Space Agency and the Federal Business Development Bank. When the Honourable Tom Hockin was appointed Minister of International Trade, Professor Higgins served as Senior Economic Advisor from 1992 to 1993. He assisted the Minister in negotiations of the NAFTA “side agreements” with the United States and Mexico.

He is currently a Director and/or Advisor to several rapidly growing Canadian corporations, and various not-for-profit organizations.

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1. INTRODUCTION

In January of 2008, building upon research completed in the spring of 2007, Professor Gerald R. Higgins of the Richard Ivey School of Business, University of Western Ontario, completed this preliminary assessment of propane as a transportation fuel for light-duty fleets in Canada ("The Study"). The Study was limited specifically to fleet applications in light-duty vehicles (vehicles under 8,500 lbs. Gross Vehicle Weight Rating (GVWR)). Typical vehicle fleets in the Study would include police patrol vehicles, urban taxis, local and regional delivery trucks, ambulances, and a variety of service vehicles. The Study did not evaluate transportation fuels for personal-use vehicles.

The propane alternative was evaluated against other transportation fuels available to fleet operators at the time of the Study. As a prerequisite for inclusion and consideration as a transportation fuel in this Study, it was a requirement that each transportation fuel be "fit for purpose" in the defined fleet application, at the time of this Study. Factors such as the availability of a vehicle platform suitable for the fleet use defined, refuelling infrastructure, security of fuel supply, vehicle operating range, refuelling time, fleet performance experience, and economic viability were evaluated to determine if the fuel alternative was "fit for purpose" as a fuel in the specific fleet application.

The objective of the Study was to compare propane as a transportation fuel with other current and viable transportation fuels, for fleet use, basing the evaluation on empirical evidence available to the general public.

Seven criteria (the "Relevant Criteria") were examined, including:

1. Life-cycle operating costs;
2. Environmental impacts;
3. Security of fuel supply;
4. Fuel price stability;
5. Refuelling infrastructure;
6. Public and Private Sector Implications; and
7. Government policies.

In addition to the most popular transportation fuel choices, gasoline and diesel fuel, other fuels were reviewed to determine their qualification for inclusion in the Study. The Author's research team reviewed Canadian Government sources such as Environment Canada, Natural Resources Canada, Transport Canada, and organizations at the Provincial level. Similarly, US Government organizations were accessed, including the US Department of Energy, and the US Department of Transportation. Information from many other sources, including universities and industry associations from both Canada and the United States were included in the research efforts.

Under the Canadian Federal Government's *Alternative Fuels Act (1995)*, alternative transportation fuels, by definition, include the following fuels: ethanol; methanol; propane gas; natural gas; hydrogen; and electricity.

Transportation fuel alternatives such as hydrogen, methanol, and electricity were eliminated from the Study, as they did not currently meet the “fit for purpose” qualification for this Study. Hybrid vehicles were excluded from this analysis as the vehicles currently available (Toyota Prius and Camry, Honda Insight, Ford Escape and others), primarily due to size, load carrying capacity, and performance capabilities, are not suited to fleet use in the defined fleet segment. While there are a number of Prius’ deployed in taxi use, the platform does not meet the requirements of the majority of the targeted fleet segment at this time. Biodiesel, although not currently defined as an alternative transportation fuel in the Alternative Fuels Act, was eliminated from the Study due to limited availability and the premium cost of the fuel.

The following Study is a comparison and evaluation of propane against the below-noted transportation fuel alternatives for light-duty fleets as defined above:

- conventional gasoline;
- gasoline/ethanol blends containing 10% ethanol (E10);
- gasoline/ethanol blends containing 85% ethanol (E85);
- conventional diesel fuel; and
- natural gas.

2. EXECUTIVE SUMMARY

The Study, based on the examination and evaluation of the seven Relevant Criteria, concluded:

> ***"The evidence is clear, irrefutable, and comes from many independent sources: Propane is the best choice of transportation fuel for light-duty fleet operators in Canada, who want to reduce operating costs, while reducing harmful emissions."***

Propane is the most cost-effective transportation fuel for light-duty commercial fleet vehicles. In order to achieve payback on the cost of conversion, the fleet vehicle must consume significant quantities of fuel, either from high-mileage and/or considerable idle time. Vehicles that accumulate over 60,000 km per year (or that consume over 14,000 litres of gasoline annually) will provide fuel cost savings of 25% over gasoline. The payback period for the cost of conversion is less than one year. Propane pricing was also found to be more stable than retail gasoline and diesel pricing.

Today's propane technology is robust and has been proven to meet the demanding requirements of severe-duty use in vehicles such as police fleets and para-transit vehicles. Propane is best suited to power light-duty vehicles (under 8,500 lbs. GVWR). Ideal applications for propane include: police vehicles; taxis; limousines; shuttle vehicles; delivery vehicles; and service vehicles. Fleet operators do not have to compromise on vehicle reliability or range to utilize propane as a transportation fuel.

In addition to fuel cost savings, propane also offers other benefits to fleet operators. It is environmentally superior to gasoline and diesel, providing life-cycle Greenhouse Gas (GHG) emissions reductions of approximately 26% relative to gasoline and providing significantly less emissions of criteria air contaminates (CAC's) and air toxics when compared to diesel. Supporting the sustainability of the cost-savings over time, there is abundant propane supply and infrastructure in Canada to meet any foreseeable increase in demand.

While diesel also offers fuel cost savings to the fleet operator, the savings are offset by the premium cost of the diesel-power option, which increases the payback period to greater than that of propane. Propane fuel costs, net of conversion costs, are 11% less than diesel fuel costs in a similar scenario. The availability of diesel engines is limited to ¾ ton and heavier pickup trucks and vans and there is no availability of diesel engines in the most popular commercial fleet passenger vehicles. Diesel emissions contribute to urban smog, and studies have shown the negative health effects of diesel particulate emissions. While biodiesel may offer some environmental benefits, supply is very limited and life-cycle operating costs will increase compared to conventional diesel.

Natural gas also offers fuel cost savings relative to gasoline; however applications for this alternative in the light-duty vehicle sector are constrained. Payback periods are greater than that of propane and cost, lack of infrastructure, and vehicle operating range, are significant disadvantages for many light-duty fleets. The application of natural gas vehicle technology has been greatest in urban transit buses where infrastructure can be provided and acceptable range can be met with a large number of CNG storage cylinders. Natural gas as a transportation fuel provides environmental benefits similar to that of propane.

Current information indicates that ethanol will be adopted as an oxygenate in gasoline-blends (up to 10% by volume) to provide incremental environmental benefits over conventional gasoline. Ethanol provides less energy content per volume than conventional gasoline, and ethanol-blended gasolines tend to be priced at or above conventional gasoline prices today. This combination of factors will increase the fuel costs to fleets and will reduce vehicle operating range between refuelling. Gasoline/ethanol blends such as E85 magnify this problem of higher operating costs and reduced range, and can become an even greater challenge when combined with the minimal availability of E85 refuelling infrastructure. Under current conditions, in the scenario evaluated, the fuel costs for E85 were double that of the propane option, net of conversion costs. While the fleet operator may achieve some environmental benefits with the use of E85 in place of conventional gasoline, those benefits will be at a significant cost to the owner. A major change in production technology is required before high-percentage ethanol blends such as E85 are cost-competitive with other fleet fuel alternatives. Until a strong supply infrastructure is developed, it is likely that ethanol prices will experience volatility.

Propane as a transportation fuel has great potential as a "made in Canada" solution: there is a domestic abundance of the fuel; it is readily available; it offers significant cost savings and it provides environmental benefits in terms of both GHG emissions and CAC reductions. Its use by fleet operators does not require vehicle performance compromises. There is also an opportunity for Canadian-developed technology to be marketed in the United States and around the world.

The report describes the detailed evidence on which the Study was able to support the following statements:

- ***"Propane as a transportation fuel is:***
    - ***25% less expensive than conventional gasoline;***
    - ***28% less expensive than E10 ethanol-blended gasoline;***
    - ***50% less expensive than E85 ethanol-blended gasoline;***
    - ***11% less expensive than diesel; and***
    - ***9% less expensive than natural gas***

  when evaluated on a full life-cycle basis, with consideration for all costs of conversion."

- ***"Propane is more environmentally friendly than gasoline or diesel, emitting up to 26% less Greenhouse Gases than conventional gasoline and significantly less emissions of criteria air contaminants and air toxics that impact air quality and human health."***

- ***"There is an abundance of propane in Canada available to meet the transportation sector needs. Propane from domestic sources could replace up to 20% of domestic gasoline demand."***

- ***"Propane pricing has been, and is likely to be, more stable than gasoline, diesel, and ethanol-blends well into the future"***

- ***"Propane is the most readily accessible and available alternative fuel in Canada, and additional infrastructure is easily installed as fleet-specific needs arise"***

- ***"Propane as a transportation fuel is ideally positioned to assist governments and the private sector with their efforts to address environmental issues."***

- ***"Propane as a transportation fuel, is most widely in use in countries where governments at all levels have introduced stable long-term policies and programs aimed at introducing and establishing propane as a mainstream competitor against conventional transportation fuels."***

3. FUELS AND ENGINE TECHNOLOGIES

With the goal of practicality, the transportation fuel alternatives to be evaluated in this Study were subjected to a “fit for purpose” review, based upon the defined fleet application. Factors such as the availability of a vehicle platform suitable for the fleet use defined, refuelling infrastructure, security of fuel supply, vehicle operating range, refuelling time, fleet performance experience, and economic viability were evaluated to determine if the fuel alternative was “fit for purpose” as a fuel in the specific fleet application.

Hybrid vehicles were excluded from this analysis as the vehicles currently available (Toyota Prius and Camry, Honda Insight, Ford Escape and others), primarily due to size, load carrying capabilities, and performance, are not suited to fleet use in the defined fleet segment. While there are a number of Prius’ deployed in taxi use, the platform does not meet the requirements of the majority of the targeted fleet segment at this time. Biodiesel was also eliminated from the Study due to limited availability and the premium cost of the fuel. Fuel cell and hydrogen-powered vehicles are still years if not decades away from being commercially available.

3.1 Gasoline

Gasoline has been used to power vehicles since the first automobiles were developed late in the 19th century. Gasoline is produced in oil refineries and is the most popular transportation fuel in the world. In Canada, approximately 38 billion litres of gasoline are sold annually.[1]

The bulk of a typical gasoline consists of various hydrocarbons with between 5 and 12 carbon atoms per molecule. Many of these hydrocarbons are considered hazardous substances and are regulated. Unleaded gasoline typically contains at least fifteen hazardous chemicals occurring in various amounts. These include benzene, toluene, naphthalene, trimethylbenzene and about 11 others. Overall, a typical gasoline is predominantly a mixture of paraffins, naphthenes, aromatics and olefins.

Over the years, gasoline formulations have changed as emission requirements and engine designs have evolved: lead has been removed; sulphur reduced; and oxygenates and other chemicals added, to enhance performance and improve emissions. Blending oxygen-bearing compounds such as methyl tertiary-butyl ether (MTBE), ethyl tert-butyl ether (ETBE) and ethanol into gasoline increase oxygen-availability within the fuel. The increased levels of oxygen improve combustion, reducing “smog” by reducing the amount of

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[1] Statistics Canada - Sales of fuel used for motor vehicles, by province and territory 2002-2006 - http://www40.statcan.ca/l01/cst01/trade37b.htm

carbon monoxide and unburned fuel that is present in the exhaust gases from the engine.

Engine technologies have also advanced over the last century as automobile manufacturers, responding to the introduction of regulations, have worked to improve power, reliability and emissions. One of the significant advancements in engine technology has been the addition of increasingly sophisticated computerized engine controls and electronics that enable on-board engine diagnostics and support engine performance and emissions optimization. Up to the late 1980's, carburetors were the primary devices used to mix gasoline with air in preparation for combustion. In the 1990's, the engine manufacturers migrated from carbureted engines to multi-port fuel injected engines, as they pursued their goals to decrease emissions, increase durability, and meet the latest requirements set in place by the US EPA.

3.2 Diesel Fuel

Diesel (or diesel fuel) is a petroleum distillate that is used to fuel compression-ignition type combustion engines. Petroleum-derived diesel is composed of about 75% parraffins and cycloparaffins, and about 25% aromatic hydrocarbons, including naphthalenes and alkylbenzenes. In North America, diesel fuel is a popular fuel choice in heavy-duty vehicles such as transport trucks and buses. In Europe, diesel is also popular in passenger cars. In Canada, approximately 16 billion litres of diesel fuel are sold annually, and this volume is increasing.[2]

Diesel fuel is very similar to the heating oil used in central heating systems. Canada, Europe and the United States place specific taxes on diesel fuel for on-road use, creating significant price differentials compared to heating oil. In many jurisdictions, heating oil is marked with fuel dyes and trace chemicals to prevent its substitution as diesel in on-road applications, and to facilitate detection of the tax fraud if substitution does occur.

Ultra-low sulphur diesel (ULSD) was set by the United State's EPA as a new standard for the sulphur content in on-road diesel fuel sold in the United States effective October 15, 2006. This new regulation applies to all diesel fuel, diesel fuel additives and distillate fuels blended with diesel for on-road use. The EPA mandated the use of ULSD fuel in model year 2007 and newer highway diesel-fuelled engines equipped with advanced emission control systems. Canada also introduced regulations for ULSD implementation in 2006. The requirements of the Canadian regulations were aligned, in level and timing, with those of the United States' EPA.

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[2] Statistics Canada - Sales of fuel used for motor vehicles, by province and territory 2002-2006 - http://www40.statcan.ca/l01/cst01/trade37b.htm

Diesel engines are more efficient than gasoline engines of the same power, and as a result, offer lower fuel consumption to vehicle operators. Diesel fuel is denser and contains about 15% more energy by volume. Naturally aspirated diesel engines are heavier than gasoline engines of the same power. The addition of turbochargers and improved materials technology is improving the horsepower to weight ratios of modern diesel engines. The increased fuel economy of the diesel engine over the gasoline engine enables the diesel to produces less carbon dioxide (CO_2) per unit of distance.

While diesel engines in North America power primarily heavy-duty and medium-duty trucks and buses, their use is increasing in light-duty vehicle applications. Larger capacity vans and pickup trucks from Ford, GM and Chrysler (usually ¾ ton and larger) are available with diesel engine options. Typically the diesel engine option list price averages $9,000 in pickups and vans. For commercial uses requiring towing, load carrying and other tractive tasks, diesel engines tend to have better torque characteristics than the other fuel options.

There are relatively few diesel-powered light-duty automobiles available in the US and Canada. Offerings are primarily from European manufacturers such as Mercedes and Volkswagen although North American and Japanese manufacturers are in the process of developing diesel offerings in the light-duty vehicle sector.

Automotive emissions from diesel-powered vehicles in North America must now meet the same emissions standards as gasoline vehicles in the same duty classification. The processes that give diesel engines efficient fuel economy also create extra emissions of certain pollutants. High compression ratios and lean air-fuel mixtures produce high combustion temperatures, which in turn create more nitrogen oxides (NO_x) and diesel particulate matter (also known as smoke) for release into the atmosphere. While the particulate matter can be controlled with higher injection pressures and particulate filters, the big challenge is limiting NO_x (Tier 2 regulations in the US are 0.05 gram per mile of NO_x, which is ⅛ of the 0.40 limit in the European Union). In order to meet the more severe emissions requirements in States such as California, sophisticated after-treatment exhaust systems are required, including the addition of catalysts, particulate filters and urea injection to enable conversion of exhaust gas streams to acceptable emissions levels.

3.3 Propane

Propane has been powering vehicles since the 1920's and was popularized as a vehicle fuel in the 1950's and 1960's. Today there are over 10 million propane-powered vehicles worldwide and the number is growing. Historically, in North America, the large original equipment manufacturers (OEM's) such as Ford, GM and Chrysler have offered, and withdrew, on occasion, a very limited number of propane-powered vehicles. The majority of the North American demand for propane-powered vehicles has been satisfied with aftermarket propane-conversion technology. Recently, Ford, through an alliance with Roush Enterprises Inc., has announced the introduction of a propane-powered pickup truck for the US marketplace beginning in 2008.

Prior to the introduction of advanced electronically-controlled engines, the propane-conversion equipment on engines consisted of a relatively simple carburetor with a rudimentary vaporizer. This carburetor-based technology continued to evolve into the 1980's and 1990's with improvements to the carburetors and with the installation of primitive electronics controlling the air/fuel mixture. During the late 1980's and early 1990's gasoline engines changed significantly. Driven by EPA emissions requirements, gasoline engine manufacturers abandoned carburetor technologies and embraced fuel-injection technology to gain precise control over air/fuel mixtures. As well, second Generation Onboard Diagnostics (OBDII) became mandatory on all engines. The propane-conversion technology providers did not keep up with the evolution of gasoline engine technology. The industry continued to install carburetor-based technology that resulted in operational problems (backfires, reliability) and poor environmental performance that rendered the carbureted propane technology unviable.

In the late 1990's North American and European technology companies began to develop propane fuel-injection technologies with sophisticated electronic controls. Typically these technologies work in combination with the OEM electronics, and utilize injectors designed specifically for propane. This technology has lead to excellent emissions results along with drivability and performance that is equivalent to gasoline. A number of these technologies are available in North America and fleets have logged millions of kilometres utilizing the technology; proving its capabilities to meet the rigors of fleet use.

As these systems have become increasingly sophisticated and more costly to manufacture, the cost of the conversion components has risen from $1,500 for the old technology in the 1980's to approximately $5,000 for the current fuel-injected technology. While the old carbureted technology is still available and still used by some low cost, non-compliant operators such as taxis, its use for major fleet operators is discouraged due to operational and emissions issues. The new generation technology is typically EPA approved for emissions, CSA and/or UL certified for safety, and meets the operational (reliability, performance, emissions, regulatory compliance) requirements of today's commercial fleet user.

3.4 Ethanol

Ethanol has been used as a vehicle fuel since the early part of the 20th century when Henry Ford converted a 1908 Model T to run on alcohol. Ethanol is flammable, colourless, volatile liquid possessing a strong odour. Hydrogen bonding causes pure ethanol to be hygroscopic, readily absorbing moisture from the air. Ethanol is produced both as a petrochemical, through the hydration of ethylene, and biologically, by fermenting sugars with yeast.

Ethanol can be produced from any feedstock containing plentiful natural sugars or starch that can be readily converted to sugar. Popular feedstocks include sugar cane (Brazil), sugar beets (Europe), wheat and corn (US and Canada). In North America, corn or wheat grain is processed to sugar in wet and dry mills. The sugar is fermented and the resulting mix is distilled and purified to obtain anhydrous ethanol. Major by-products from the ethanol production process include dried distillers' grains and solubles, which are suitable for animal feed.

Cellulosic ethanol is produced from lignocellulose, a structural material that comprises much of the mass of plants. It is composed mainly of cellulose, hemicellulose and lignin. Corn stover, switchgrass, miscanthus and woodchips are some of the more popular cellulosic materials for ethanol production. Cellulosic ethanol is chemically identical to ethanol from other sources, such as corn starch or sugar, but has the advantage that the lignocellulose raw material is highly abundant and diverse. It does, however, require a greater amount of processing to make the sugar monomers available to the microorganisms that are typically used to produce ethanol by fermentation.

The Canadian firm, Iogen, brought the first pilot scale cellulose-based ethanol plant on-stream in 2004. This technology could turn a number of cellulose-containing agricultural by-products, such as corncobs, straw, and sawdust, into renewable energy resources. To date, high capital costs have prevented the development of any commercial cellulosic ethanol plants in the United States or Canada. The Canadian Government has invested heavily in the commercialization of cellulosic ethanol and a production scale pilot plant is planned for Ontario.

Nearly all Canadian ethanol production is blended into gasoline at up to 10% by volume, to produce a fuel called E10. All cars and light-duty gasoline-powered trucks built for the North American market since the late 1970's can run with a gasoline/ethanol blend of up to 10%.

Automakers (primarily Ford, GM and Chrysler) produce a number of Flexible Fuel Vehicles (FFV's) for the North American market that can run on any blend of gasoline and ethanol up to 85% ethanol by volume (E85). More than 5 million FFV's were produced for the US market from 1992 through 2005, because auto manufacturers were able to use FFV sales to offset US corporate average fuel economy (CAFE) requirements to avoid significant penalties.[3] The FFV offering continues to be expanded in the US and Canada with additional FFV models becoming available in 2006 and 2007. Gasoline vehicles require minimal modifications at the OEM level to operate on E85. One or more sensors

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[3] Energy Information Administration – Biofuels in the US Transportation Sector – Originally published in the Annual Energy Outlook 2007, February 2007, Washington, DC.

automatically detect the fuel mixture and the engine control unit tunes the timing of spark plugs and fuel-injectors so that the fuel will burn properly in the vehicle's engine. As E85 is more corrosive, special fuel system materials are also required. Typically an OEM FFV does not command a premium price at the retail level.

Ethanol, and ethanol-blended gasoline, because of its ability to pick up water, cannot be transported by pipeline. Ethanol can be shipped by railcar or truck but must be blended at the terminal for those locations supplied by marine or pipeline. Dedicated tanks are required to store the ethanol and the gasoline-blending component with which it will be mixed. The handling of ethanol-blended fuels also requires modifications to the other aspects of the fuel distribution system, including trucks, retail storage tanks, and service station pumps.

3.5 Methanol

Methanol is the simplest and lightest of the alcohols, and is produced primarily from natural gas. The use of methanol as a motor fuel, received attention during the oil crises of the 1970's due to its availability and low cost. Problems occurred early in the development of gasoline-methanol blends. It is corrosive to some metals, including aluminium, so modifications to the gasoline fuel delivery systems are required to accommodate methanol use. It is highly toxic raising safety concerns. Its energy content is approximately half that of gasoline by volume, severely limiting its operating range or demanding large on-board fuel storage. Methanol, due to its high octane rating and high heat of vaporization, can offer increased thermal efficiency and increased power output, compared with gasoline in spark-ignited engines.

Methanol, when produced from natural gas, offers limited life-cycle GHG emissions reductions relative to gasoline. This minimal environmental benefit, combined with the storage and handling issues associated with methanol have eliminated most efforts to promote it as a vehicle fuel in North America. OEM's did build some methanol capable FFV's in the 1990's, but these efforts have been discontinued and methanol is no longer being touted as an alternative transportation fuel for internal combustion engines. There are no methanol refuelling stations in Canada.

Methanol can be used to make methyl tertiary-butyl ether (MTBE), an oxygenate that is blended with gasoline to enhance octane and create a cleaner burning fuel. MTBE production and use has declined in recent years because it was found to contaminate ground water. Ethanol, to a large extent, has replaced MTBE as an oxygenate in gasoline. The methanol industry is promoting methanol as a hydrogen source for hydrogen fuel cell technologies and researchers are currently looking at ways to overcome the barriers to using methanol.

3.6 Hydrogen

Hydrogen has the potential to revolutionize transportation, despite the fact that commercialization is still years, if not decades, away. Hydrogen can be produced from fossil fuels (reforming natural gas), biomass, and the electrolysis of water (extracting hydrogen from water using electricity). Life-cycle emissions of hydrogen fuel cell vehicles are dependent upon the method of attaining the hydrogen. The source of the electricity has a major impact on the life-cycle emissions of hydrogen-derived from electrolysis.

The US EPA estimates a 41.4% reduction in GHG emissions for a hydrogen fuel cell vehicle relative to a gasoline vehicle based on life-cycle emissions if the hydrogen source was natural gas. This estimate is derived using natural gas to produce hydrogen and accounts for the higher per mile efficiency of hydrogen in a fuel cell vehicle.[4] Hydrogen developed from electrolysis actually increases the life-cycle GHG emissions compared to conventional fuels, due to the high energy inputs required in the production of the hydrogen.

Hydrogen is not currently offered as a widespread automotive fuel. Like the fuel cell technology for automotive applications, hydrogen production, transportation, and storage (both on-ground and on-vehicle) continues to face technological challenges and continued development is required. Today, hydrogen onboard a vehicle must be stored in specialized, thick-walled, heavy, high pressure (up to 10,000 psi) tanks. These tanks hold relatively small amounts of energy for their size and significantly limit the operating range of the vehicle. Once hydrogen technology barriers are overcome, it is anticipated that the development of a hydrogen-refuelling infrastructure will require additions to the existing natural gas transmission and delivery infrastructure.

Automakers and others have varying views on the timelines for hydrogen vehicles and hydrogen infrastructure to become commercially available. Recently Ballard Power Systems Inc., a leading proponent of fuel cell technology withdrew from the automotive market, focusing its efforts on stationary and other non-automotive applications. The 2015 to 2020 timeframe is generally viewed as being a reasonable timeframe for the technology issues to be overcome and for hydrogen as a transportation fuel to become commercially available.

3.7 Natural Gas

Natural gas can be used as vehicle fuel in a gaseous (compressed) state (CNG) or a liquefied (refrigerated) state (LNG). Similar to propane, because of the relatively simple chemical structure of natural gas in comparison to

[4] US EPA – Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use – April 2007

traditional vehicle fuels, there are fewer toxic and carcinogenic emissions from natural gas vehicles and virtually no particulate emissions.[5]

Currently, the only natural gas light-duty vehicle available in the US market is the Honda Civic GX. There are no OEM natural gas light-duty vehicles available in Canada. The majority of the natural gas vehicle market for light-duty vehicles has been met with aftermarket conversion technology. There are, however, a number of heavy-duty vehicles available on natural gas (CNG or LNG). These are transit buses, heavy-duty tractors and medium-duty trucks. These vehicles are generally powered by compression-ignition engines converted to spark ignition engines by the major engine manufacturers such as Cummins. The market for natural gas heavy-duty vehicles and transit buses is more developed in the US than in Canada primarily due to Federal Government incentives for urban non-attainment areas to replace their diesel-fuelled buses and trucks.

Similar to propane, natural gas as a vehicle fuel experienced setbacks in the 1990's as the outdated carbureted technology caused operational and emissions issues for fleet users. Like the propane industry, the natural gas industry has now moved to fuel-injection technologies and is consistently achieving excellent emissions results and reliable performance. High conversion costs and limited government incentives have caused the market for natural gas-powered vehicles to decline in recent years. Conversion costs remain high relative to other alternative fuels, as the high-pressure cylinders are costly and often, multiple cylinders are required to yield the operating range required for a fleet user.

Refuelling infrastructure is relatively expensive with capital costs in the $250,000 to $2,000,000 range, depending upon capacity. As a result, there are only about 100 natural gas refuelling sites in Canada. It should also be noted that vehicle refuelling rates for natural gas are much slower than liquid fuels and propane.

3.8 Electric and Hybrid Vehicles

An electric vehicle, or EV, is a vehicle with one or more electric motors for propulsion. The energy used to propel the vehicle may be obtained from several sources including on-board generation (using fuel cell technology); onboard rechargeable energy storage systems (battery electric vehicles); direct connection to land based generation plants (trolley buses); and a combination system featuring both an on-board rechargeable energy storage system and a fuelled propulsion power source (internal combustion engine).

In the early part of the 20th century, electric cars and rail transport were commonplace. Electric vehicles were among the earliest automobiles, in use

[5] www.naturalgas.org/environment/naturalgas

before the advent of the lighter, more powerful internal combustion engines. Over time, their general-purpose commercial use became reduced to specialist roles in platform trucks, forklift trucks, tow tractors, trolley buses and urban delivery vehicles. Electric automobiles re-appeared in the 1990's. The California Air Resources Board mandated major-automaker sales of EVs, in phases starting in 1998. From 1996 to 1998, GM produced 1117 EV1s, 800 of which were made available through 3-year leases. Chrysler, Ford, GM, Honda, Nissan and Toyota also produced limited numbers of EVs for the California market. GM crushed the EV1's upon lease expiry. Honda, Nissan and Toyota also repossessed and crushed most of their EVs, which, like the GM EV1s, had been available only by closed-end lease.

Electric motors are mechanically very simple, and release virtually no air pollutants at the place where they are operated. They can also be combined with regenerative braking systems that have the ability to convert/re-cycle movement energy back into stored electricity. Regenerative braking systems can reduce the wear on brake systems and reduce the total energy requirement of a trip, especially in start-and-stop city-use applications. Another advantage is that electric vehicles typically have less vibration and noise pollution than a vehicle powered by an internal combustion engine, whether it is at rest or in motion. Although electric vehicles have few direct emissions, all rely on energy created through electricity generation, which has its own emissions footprint. The US EPA estimates that electric vehicles on a life-cycle basis will reduce GHG emissions by 46.8% relative to gasoline.[6] The generating emissions were calculated on the national average CO_2 output rate for electricity in 2004, based on the EPA eGRID database. Most EV's use batteries which produce an environmental impact that emanates from their construction, their use and their ultimate disposal. Typically, the battery's environmental footprint has not been factored into the life-cycle emissions of the transportation fuel.

There are a variety of battery choices, each presenting the user with various combinations of disadvantages including expense, short useful life, range, and significant weight considerations (up to 50% of the total vehicle weight). The efficiency and storage capacity of the current generation of common deep cycle lead acid batteries decreases with lower temperatures, and diverting power to run a heating coil reduces efficiency and range by up to 40%. None of the automakers provided electric demonstration or test vehicles in Canada due to the winter temperatures. Battery and energy storage technology is advancing with improvements to life, weight and range. Costs of the technology are gradually decreasing as the technology matures and production volumes increase.

There currently are no electric vehicles manufactured by the major automakers. EV's are currently available as neighbourhood electric vehicles (NEVs) and as

[6] US Environmental Protection Agency – Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use – EPA 420-F-07-035 April 2007

scooters and bicycles. Several start-up companies, like Tesla Motors, Zenn Motor Company and Phoenix Motorcars, plan to have battery-electric vehicles available to the public in 2008, primarily marketing these vehicles in the South Western United States. A number of small entrepreneurs currently convert gasoline-powered vehicles to battery-electric vehicles. These conversions range in cost from $10,000 to $20,000. The conversions to all electric power do not require EPA certification and are often performed by amateurs.

The last few years have seen the emergence of hybrid electric vehicles. A hybrid electric vehicle (HEV) is a vehicle that combines an internal combustion engine (usually gasoline powered) with an electric motor(s) and an on-board rechargeable energy storage system. The engine powers an electrical generator to either recharge the batteries or directly feed power to an electric motor that drives the vehicle. Modern HEV's have sophisticated software and hardware to manage the various power functions to optimize fuel consumption as well as recapturing energy through regenerative braking. Most HEV's reduce fuel consumption and emissions by shutting down the engine at idle and restarting when required. Typically an HEV's engine is smaller and runs at optimal speeds to capture efficiency.

HEV's became available to the public in the 1990's with the introduction of the Honda Insight and Toyota Prius. HEV's are primarily targeted as urban commuting vehicles for private individuals. Toyota has expanded its offering to the luxury and SUV markets, and Ford has a hybrid Escape on the market. General Motors had a light duty pickup (1500 series) available as a mild hybrid in 2006 and 2007 and is in the process of introducing a number of hybrid vehicles to the market in 2008. Nissan also introduced its Altima hybrid. It is estimated that 180,000 HEV's were sold in the US in the first half of 2007 or about 3% of car sales during that period.

Plug-in hybrid electric vehicles (PHEV's) are an extension of HEV logic. These vehicles are capable of carrying a base charge of electricity (charged at home over night for example) and only use traditional fuels when it is necessary to extend the range past the pre-loaded battery-only capacity. GM has unveiled a concept car, the plug-in hybrid Chevrolet Volt, which uses a small internal combustion engine to power an electric generator that in turn, recharges the onboard batteries after the original charge capacity is depleted. As of September 2007, plug-in hybrid (PHEV) electric passenger vehicles are not yet in production. Toyota, General Motors and Ford have announced their intention to introduce production PHEV automobiles. Toyota obtained permission in July 2007 to sell their plug-in Prius in Japan. Aftermarket conversion kits and services are available to convert production model hybrid vehicles (primarily Prius) to PHEV's that have had plug-in charging added and their electric-only range extended.

Fuel cells used to generate on-board electricity, without the need for battery storage, are still under development and are not yet feasible as a transportation alternative.

Currently there are no hybrid vehicles available that would be suitable for use in the fleet segment that is the focus of this Study. There are no large HEV or PHEV passenger cars, pickups or vans available for commercial fleets. It is anticipated that as platforms are updated and revised power trains are developed, hybrid availability will be expanded to these markets. While HEV's offer moderately lower tailpipe emissions through reduced gasoline consumption, the life-cycle emissions associated with their use continues to be the subject of continued studies and discussion. If one assumes that the manufacturing footprint for the base automobile is similar, some additions to the emissions footprint for the HEV's is required to account for the extraction of the primary battery materials (nickel, etc) as well as the disposal of the battery materials once the vehicle is no longer serviceable. Further studies are being done in this area.

4. ANALYSIS AND RESULTS

4.1 Life-Cycle Operating Costs

The research team concluded that:

"Propane as a transportation fuel is:

- ***25% less expensive than conventional gasoline;***
- ***28% less expensive than E10 ethanol-blended gasoline;***
- ***50% less expensive than E85 ethanol-blended gasoline;***
- ***11% less expensive than diesel; and***
- ***9% less expensive than natural gas***

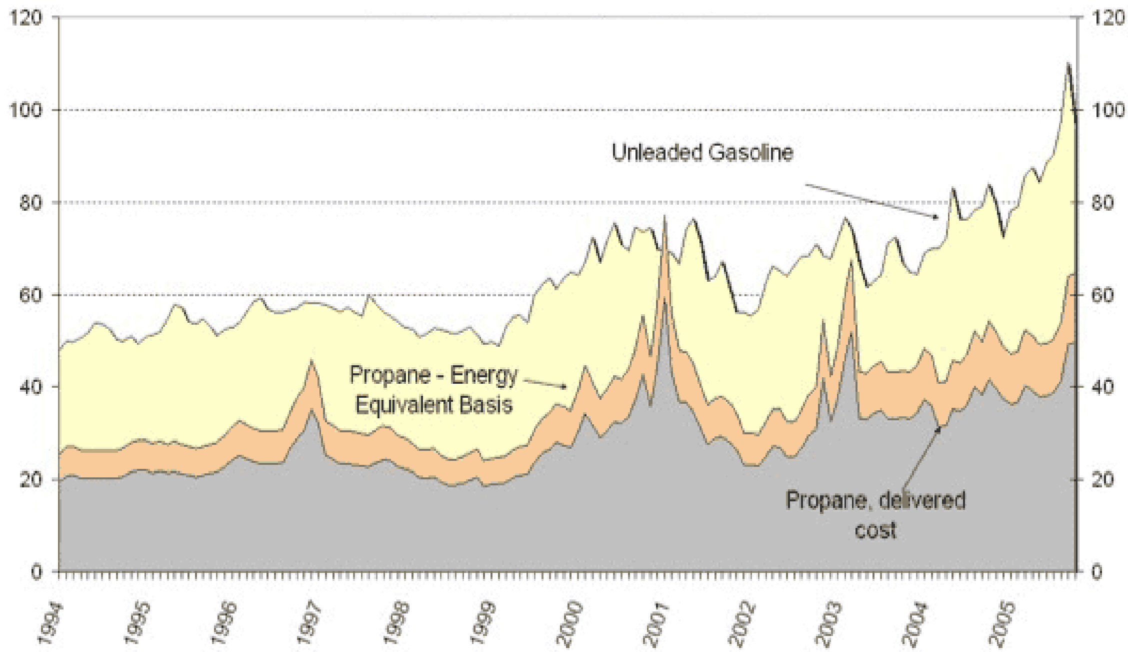
when evaluated on a full life-cycle basis, with consideration for all costs of conversion."

4.1.1 Propane is cheaper than conventional gasoline, on a net fuel cost basis adjusting for energy content and consumption.

Propane, on a per litre basis, has less energy content than a litre of gasoline. Proper comparisons of costs must be completed on a consumption equivalent basis. Chart 1 below illustrates the 11-year historical cost advantage of propane over conventional gasoline in Ontario. The grey area details the price of a litre of propane and the orange area demonstrates the adjustment of the propane cost to an energy equivalent basis with gasoline, to facilitate proper comparison. The light yellow area shows the cost advantage of propane on a net energy equivalent basis when compared to conventional gasoline. The comparison clearly indicates that the cost of propane, on average, is approximately 40% cheaper than the cost of gasoline. It is important to note that the savings, on an energy equivalent basis, between propane and ethanol-blended gasolines will be larger than it is with conventional gasoline, as ethanol by volume has less energy content than the volume of gasoline it has replaced. As ethanol percentages rise within a litre of gasoline, the savings offered by propane in comparison will rise as well.

Chart 1

Fleet Fuel Cost Comparisons - Historical Monthly Averages



January 1994 to October 2005, monthly average costs per litre in Ontario[7]

4.1.2 Costs of conversion and capital expenditures must be factored in to the overall fuel cost equation.

The use of propane or natural gas requires the installation of equipment to enable the vehicle to operate on the alternative fuel. The costs of converting the vehicle to operate on an alternative fuel have been factored into the life-cycle cost calculations in this document. Diesel-powered vehicles demand a capital cost premium over gasoline-powered vehicles. Average costs of the diesel engine option have been considered in the same manner as alternative fuels conversion costs when used to calculate the overall life-cycle costs of diesels. Flex Fuel Vehicles have minimal incremental costs to the OEM's and typically, there is no purchase premium.

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[7] Ontario Ministry of Energy – Fuel Prices Database – www.energy.gov.on.ca

4.1.3 *After all costs of conversion are factored in; propane offers the lowest life-cycle fuel costs in light-duty fleet applications.*

4.1.3.1 Fleet Application

The life-cycle fuel costs were developed for a typical high consumption fleet such as a police or urban delivery fleet. The costs were based on a vehicle life of three years for a vehicle travelling 60,000 kilometres per year. The consumption per kilometre included idle time. Fuel costs were based on the Ontario Ministry of Energy, Fuel Prices database published on their website for the month of May, 2007 for regular unleaded gasoline, propane, diesel and compressed natural gas. E85 and E10 costs were based on pricing obtained from the supplier in South-western Ontario as of October 2007.

4.1.3.2 Gasoline

The results of the comparison show that over the three-year life-cycle, propane is 25% less expensive than gasoline. A fleet operating on propane instead of gasoline, under the conditions described above, would save approximately $5,650 per year in fuel costs and pay for the conversion cost within the first 12 months. The savings would be even greater when compared to ethanol-blended fuels, as this fuel is higher in cost relative to gasoline and produces few kilometres per litre (or miles per gallon) than conventional gasoline. Although favourable to propane's economic evaluation, the premium that fleet owners are able to receive on the disposition of a used propane-powered vehicle to the secondary purchaser has not been factored into the life-cycle cost calculation. An additional benefit to fleet operators is that propane is not easily pilfered from in-yard refuelling dispensers.

4.1.3.3 Diesel

While diesel fuel costs are comparable to propane fuel costs over the life of the vehicle, the higher cost of the diesel option increases the diesel life-cycle costs over that of propane. Biodiesel was not evaluated in the comparison but the cost of biodiesel will be higher than conventional diesel and will increase the overall life-cycle costs to the fleet operator.

4.1.3.4 Natural Gas

Natural gas also offers fuel cost savings when compared to gasoline, but it has limited application in passenger cars and light-duty trucks because of the limited range of the vehicle. CNG storage cylinders equivalent in size to a gasoline tank would hold approximately the equivalent of 27 litres of gasoline. Adding cylinders to increase range will also increase weight, reduce performance, reduce payload, and reduce available cargo capacity. Natural gas is more ideally suited to urban transit buses where a large number of storage cylinders can be mounted on the buses and the vehicles are centrally refuelled during off-hours (minimizing the disadvantages of long refuelling times). LNG was not evaluated as its applications are limited to heavy-duty vehicles and the cost of conversion is approximately an additional $10,000 for the specialized cryogenic tank.

4.1.3.5 Blended Gasolines and Diesel Fuels

E85 will significantly increase the fuel costs to the fleet operator. While there is no additional cost for a FFV, the fuel costs are significantly higher for ethanol-based fuels, even after consideration of the excise tax and road tax reductions. Any blend of ethanol will increase fleet operating costs and will reduce the range of the vehicle compared to conventional gasoline. Availability of E85 may be a significant challenge as there are currently only three refuelling stations in Ontario.

While E85, E10 and biodiesel all have the potential to reduce GHG emissions compared to gasoline, each represent additional fuel costs to the fleet operator. Diesel can reduce GHG emissions and life-cycle costs to the fleet operator but diesel emissions contribute significantly to air quality issues and health concerns as explained in section 4.2.2. The diesel engine option for trucks and vans is limited to vehicles of ¾ ton and heavier. In passenger car applications, diesel is only currently available in premium European passenger cars, although it is anticipated that more diesel-powered passenger vehicles will be made available to the North American market in the future.

4.1.3.6 Propane

Propane offers the lowest overall life-cycle fuel costs, while at the same time reducing GHG emissions and improving air quality. Propane has the further advantage of offering fuel-operating ranges similar to its gasoline and diesel counterparts. Propane technology has been developed and is available for the most popular fleet vehicles such as large passenger cars, vans and trucks.

4.1.3.7 Quantitative Comparison of Life-Cycle Fuel Costs

Table 1 compares total life-cycle fuel costs, including upgrade or conversion costs, for fleet vehicles running on different fuels.

Table 1
Comparative Costs for Fleet Vehicles
Diesel, Natural Gas and Propane versus Gasoline and Ethanol Blends

	Gasoline	Gasoline with 10% Ethanol (E10)	Gasoline with 85% Ethanol (E85)	Diesel	Natural Gas (CNG)	Propane
Assumptions Evaluated						
Distance to be traveled (km) – over 3 year life	180,000	180,000	180,000	180,000	180,000	180,000
Litres/100 km*	23.54	24.25	32.49	16.95	23.54	28.25
Price / litre **	$1.073	$1.090	$1.173	$0.951	$0.707	$0.561
Fuel Consumed (litres)	42,372	43,643	58,473	30,508	42,372	50,846
Cost of Fuel Consumed	$45,465.16	$47,571.04	$68,589.25	$29,012.96	$29,957.00	$28,524.83
Conversion Cost vs. Conventional Gasoline	N/A	N/A	N/A	9,229.00	7,550.00	5,634.00
Total Cost of Fuel and Conversion	$45,465.16	$47,571.04	$68,589.25	$38,241.96	$37,507.00	$34,158.83
Cost Comparison vs. Gasoline						
Total Savings(Costs) produced by fuel cost differentials	**N/A**	($2,105.89)	($23,124.10)	$16,452.20	$15,508.15	$16,940.33
Upgrade Costs vs. Gasoline***	**N/A**	$0.00	$0.00	$9,229.00	$7,550.00	$5,634.00
Net Savings(Costs) after upgrade costs	**N/A**	**($2,105.89)**	**($23,124.10)**	**$7,223.20**	**$7,958.15**	**$11,306.33**
% Savings(Costs) net of upgrade costs	**N/A**	**(5%)**	**(51%)**	**16%**	**18%**	**25%**
Cost Comparison vs. E10						
Total Savings(Costs) produced by fuel cost differentials	$2,105.89	**N/A**	($21,018.21)	$18,558.09	$17,614.04	$19,046.21
Upgrade Costs vs. E10	$0.00	**N/A**	$0.00	$9,229.00	$7,550.00	$5,634.00
Net Savings(Costs) after upgrade costs	**$2,105.89**	**N/A**	**($21,018.21)**	**$9,329.09**	**$10,064.04**	**$13,412.21**
% Savings(Costs) net of upgrade costs	**4%**	**N/A**	**(44%)**	**20%**	**21%**	**28%**
Cost Comparison vs. E85						
Total Savings(Costs) produced by fuel cost differentials	$23,124.10	$21,018.21	**N/A**	$39,576.30	$38,632.25	$40,064.42
Upgrade Costs vs. E85	$0.00	$0.00	**N/A**	$9,229.00	$7,550.00	$5,634.00
Net Savings after upgrade costs	**$23,124.10**	**$21,018.21**	**N/A**	**$30,347.30**	**$31,082.25**	**$34,430.42**
% Savings(Costs) net of upgrade costs	**34%**	**31%**	**N/A**	**44%**	**45%**	**50%**
Cost Comparison vs. Diesel						
Total Savings(Costs) produced by fuel cost differentials	($16,452.20)	($18,558.09)	($39,576.30)	**N/A**	($944.05)	$488.13
Upgrade Costs vs. Diesel	($9,229.00)	($9,229.00)	($9,229.00)	**N/A**	($1,679.00)	($3,595.00)
Net Savings after upgrade costs	**($7,223.20)**	**($9,329.09)**	**($30,347.30)**	**N/A**	**$734.95**	**$4,083.13**
% Savings(Costs) net of upgrade costs	**(25%)**	**(32%)**	**(105%)**	**N/A**	**3%**	**11%**
Cost Comparison vs. CNG						
Total Savings(Costs) produced by fuel cost differentials	($15,508.15)	($17,614.04)	($38,632.25)	$944.05	**N/A**	$1,432.18
Upgrade Costs vs. CNG	($7,550.00)	($7,550.00)	($7,550.00)	$1,679.00	**N/A**	($1,916.00)
Net Savings after upgrade costs	**($7,958.15)**	**($10,064.04)**	**($30,347.30)**	**($734.95)**	**N/A**	**$3,348.18**
% Savings(Costs) net of upgrade costs	**(27%)**	**(34%)**	**(104%)**	**(2%)**	**N/A**	**9%**

Notes:

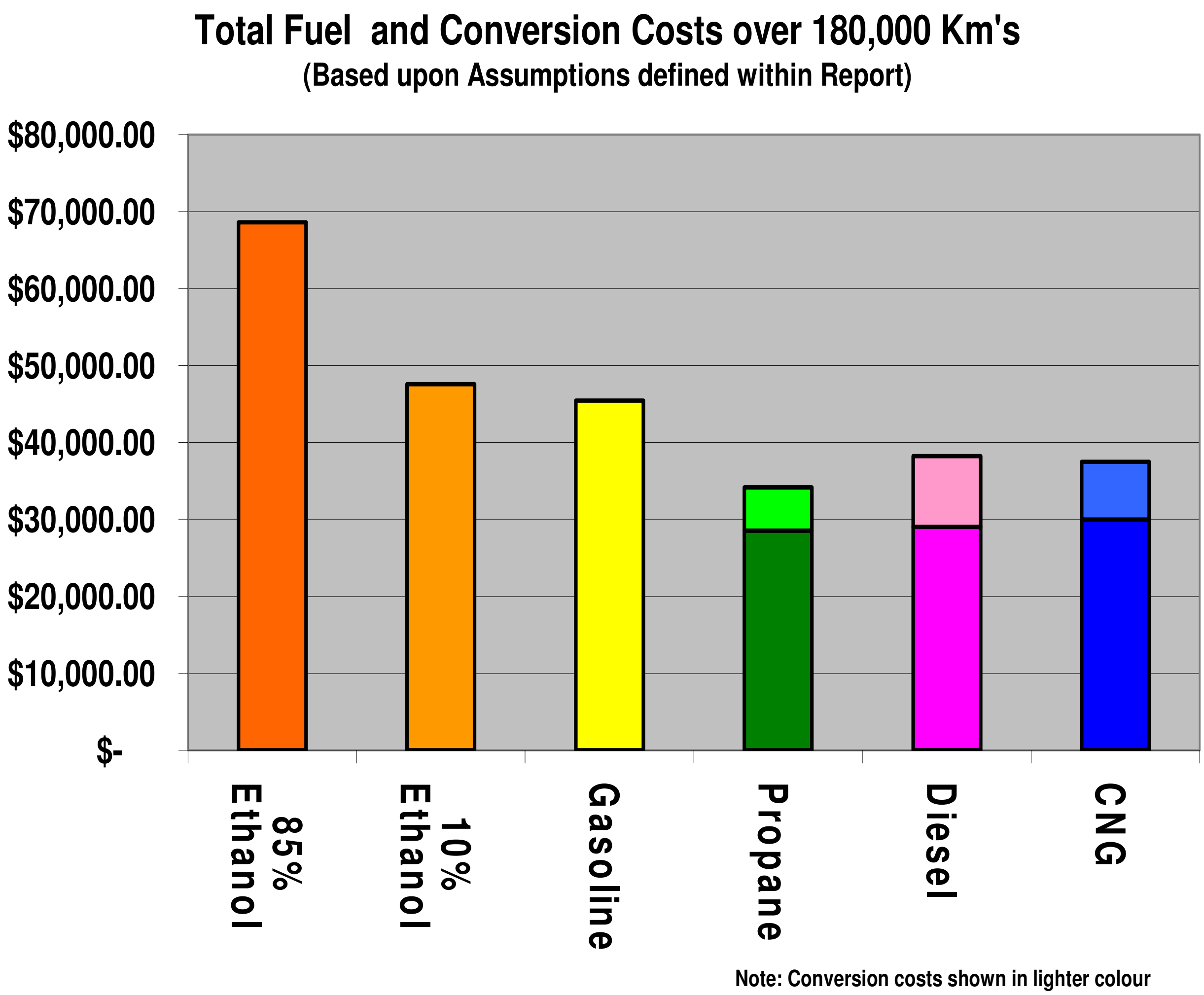
* Idle time considered in consumption per 100 km. – using 12 mpg on gasoline, ethanol composition would increase consumption per 100km due to factoring of energy equivalency of ethanol by volume, propane vehicle consumption based upon actual experience, all others based on EPA ratings for equivalent vehicles relative to gasoline. CNG consumption and CNG fuel costs are based on gasoline equivalent

** Prices based on May 2007, Southern Ontario average monthly price for gasoline, diesel, propane and CNG as published by Ontario Ministry of Energy, E85 price quoted from UPI in South-western Ontario – October 2007

*** Upgrade/conversion costs include applicable cost include GST and PST less any rebates – Ontario shown

The total fuel cost to fleet operators can be dramatically different between fuel choices, after accounting for all costs of conversion. Based upon the analysis in Table 1 above, Chart 2 below illustrates the total fuel costs of each fuel option.

Chart 2



An important benchmark for fleet operators is their cost per distanced travelled. The following table shows the relative costs per 100 km travelled, based on the data in Table 1. Propane clearly has the overall lowest cost for fuel including the cost of conversion.

Table 2

Fuel Cost per 100 km of Travel
Includes conversion cost

Fuel	Cost per 100 km
Propane	$18.98
Natural Gas (CNG)	$20.83
Diesel	$21.25
Gasoline	$25.26
Gasoline with 10% Ethanol	$26.43
E85 (gasoline with 85% Ethanol)	$38.11

While the economic benefits of diesel, CNG and propane appear relatively close; there are other factors that become significant differentiators. For example, the following are just a few of the other factors that need to be considered: natural gas vehicle performance is not identical to gasoline in terms of responsiveness; natural gas vehicle range is typically much less than gasoline; natural gas refuelling time is significantly longer than gasoline (and could be more difficult to locate); diesel model choices may not be available for the particular fleet application; and, the environmental emissions footprint for diesel is greater when compared to natural gas or propane.

4.1.4 The following four case studies demonstrate that propane, as a transportation fuel, has delivered, and continues to deliver, significant cost-savings, equivalent vehicle performance, and a number of other benefits on a consistent basis over long periods of time.

4.1.4.1 Case Study: The London Police Service, London Ontario

A decision by the police force in London, Ontario, to convert much of its fleet to run on propane has saved taxpayers millions of dollars in fuel costs over the past 20 years.

In 1982, the London Police Service tested propane as an alternative fuel in two of the Service's Fleet vehicles. The results were so encouraging that today close to 65 percent of the vehicles in the Fleet have been converted to run on propane. This includes 71 full-sized sedans and 20 trucks and vans.

According to Gar Irwin, who manages the London Police Service fleet, the remaining vehicles have not been converted because they either have low annual mileage or are used in surveillance projects and, as propane vehicles, cannot be adequately camouflaged. However, 41 unmarked cars run on a fuel blend of ethanol and gasoline.[8]

Based on twenty years of environmentally responsible operations, no discernible difference in vehicle performance, a perfect safety record and operating savings in the millions of dollars, the London Police Service continue to maintain and update their fleet with propane-powered automobiles.[9]

4.1.4.2 Case Study: Peel Region's TransHelp (Para transit service)

The Peel Region of Ontario is one of Canada's fastest growing communities with a population of 1.1 million covering 480 square miles. It includes the cities of Mississauga and Brampton. TransHelp was founded in 1981 in order to provide para transit service to individuals unable to use conventional transit, such as those with a physical disability or confined to a wheelchair. The TransHelp's vehicle Fleet consists of 40 buses: 3 with 7.5 litre engines, 9 with 6.8 litre engines and 28 with 5.4 litre engines, all of which use the Ford E-350 chassis. Annually, this Fleet makes over 220,000 one-way trips to and from residences, hospitals, therapy centres, shopping, and other destinations. This Fleet travels on a combination of major highways, urban streets, and rural roads. Each vehicle serves for 7 years in front line service, followed by 3 years of backup service, and has a typical life span of between 375,000 and 425,000 kilometres.

While in service, TransHelp vehicles are often waiting for users for long periods of time, idling in emissions-sensitive areas such as hospital laneways and community centres. Though there is a fuel cost penalty, idling is unavoidable. The vehicles' engines have to be left running to keep the interior warm in winter and cool in summer. Due to the areas in which the vehicles operate and the individuals they serve (who are often in need of health care), vehicle emissions must be monitored so that the health of those in close proximity – either on board or in the surrounding area – is not adversely affected.

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[8] FleetSmart: Office of Energy Efficiency, Natural Resources Canada, 580 Booth Street, 18th Floor, Ottawa ON K1A 0E4

[9] Richard Ivey School of Business, The University of Western Ontario, Case Study prepared by Ivey MBA Students, February 2007

The successful deployment of propane technology has enabled TransHelp to continue to deliver a high level of service to its customers while ensuring health and safety concerns are minimized. Through its Green Tree Project, and the associated logo displayed on each of its vehicles, TransHelp has increased the visibility of environmentally friendly fuels. In addition to the environmental benefits, TransHelp has been able to realize a fuel savings of 15-20% over gasoline (dependant on fuel price), and receives an additional federal transit rebate of 15% for the conversion cost.[10]

4.1.4.3 Case Study: United Parcel Service (UPS) Canada Ltd., Mississauga, Ontario

United Parcel Service (UPS) Canada Ltd. began testing propane as an alternate fuel source as early as 1985. A major commitment to propane was made in 1989 and a conversion program was completed in conjunction with an engine replacement program undertaken during the same time frame.

> *Propane conversions were implemented as UPS Canada converted its Fleet from 292 CID carbureted engines to 4.3 litre electronically controlled engines. This not only reduced the cost of conversion, but also allowed for implementation at a much faster rate.*
>
> *EIGHTEEN-MONTH PAYBACK ON PROPANE CONVERSIONS. The conversions cost a total of CAN$1 million, for both the purchase and installation of the engines and the propane conversion. All work was done by in-house mechanics to control quality and cost. Savings have been $1.3 million per year. This reflects savings in operating costs based on the lower cost of propane versus gasoline. Operating efficiency has not been affected as the engines and vehicles operate as they did with gasoline engines. Payback on the project was less than 18 months.*
>
> *NEWER ALTERNATE FUEL TECHNOLOGIES. UPS Canada continues to explore and test other alternate fuels. The company currently operates 912 Compressed Natural Gas and Liquid Natural Gas vehicles in 17 locations in the United States, with plans to add more sites and vehicles in 1999.*[11]
>
> *Propane's low pollution characteristics and positive performance have made it a viable choice for inclusion in UPS's alternative fuel Fleet.*[12]

UPS was satisfied with its decade-long experience with a propane-powered Fleet and announced, on October 8, 2007, an expansion of its North American

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[10] Richard Ivey School of Business, The University of Western Ontario, Case Study prepared by Ivey MBA Students, February 2007
[11] United Parcel Service's Alternate Fuels Program: MTE, Moving the Economy On-line,
[12] UPS.com

propane Fleet by 23%. Propane powered vehicles now account for almost 45% of UPS's global fleet of alternative-fuel vehicles.

4.1.4.4 Case Study: Propane vs. Diesel: Operating Savings at Northside ISD, San Antonio, Texas.

Northside Independent School District has a service area of 360 square miles, encompassing North West San Antonio and nearby Bear County. The bus fleet transports over 32,000 students daily in 472 vehicles, 94% (430) of which have run on propane since 1980.

> "*Northside ISD saves $1,335.00 per year, per vehicle in fuel and maintenance costs using Propane versus Gasoline according to the Texas Railroad Commission's Life Cycle Cost Benefit Analysis. Cost savings using Propane versus Diesel are $1,100.00 per year, per vehicle. Conversion costs are paid back in approximately 1.4 years. Northside ISD operates an 18 year retirement program on its vehicles.*"[13]

Comparing propane to diesel and assuming a 16.6 year life expectancy, after the conversion costs are recouped, Northside can expect savings of over $18,000 per vehicle. That amounts to over $8.4 million in savings over the life of the fleet. Cost savings of a similar magnitude are being reaped by other school districts all over North America.

As the case studies above demonstrate, propane as a transportation fuel can be deployed with great success, unlocking significant fuel savings and many other benefits.

[13] Northside Independent School District, Transportation Bulletin, San Antonio, Texas, 2002.

4.2 Environmental Impacts

The research team concluded that:

"Propane is more environmentally friendly than gasoline or diesel, emitting up to 26% less Greenhouse Gases than conventional gasoline and significantly less emissions of criteria air contaminants and air toxics that impact air quality and human health."

4.2.1 On a Well-to-Wheels basis, propane emits up to 26% less Greenhouse Gases than conventional gasoline

Propane as a transportation fuel can make a contribution to improving air quality and reducing GHG emissions. The US Department of Energy's Argonne National Laboratory (ANL) examined the full life-cycle Greenhouse Gas (GHG) emissions of propane[14] as compared to other motor fuels. ANL focused on propane as a transportation fuel and analyzed the emissions data in two distinct stages: well to pump (WTP), and pump to wheel (PTW). At the WTP stage, ANL discovered that using propane, in place of diesel, conventional gasoline, or reformulated gasoline, led to a 50% decline in emissions. The ANL study concluded that compared to conventional transportation fuels, propane can reduce full life-cycle GHG emissions by as much as 12 to 20%.[15] Other studies support these conclusions although the numbers vary due to different assumptions and variables.

The Center for Clean Air Policy estimated that a fleet of light-duty GVW vehicles (cars and trucks weighing less than 8,500 lbs.) could achieve a 26% reduction in GHG emissions by utilizing propane fuel instead of gasoline. This 26% reduction in GHG emissions versus gasoline was quantified with ANL's "GREET Model lifecycle", which estimated total GHG emissions during fuel production, fuel use and vehicle operation.[16]

A recent Glotec report demonstrated that propane emitted between 15% and 27% less gm/mi. of GHG than conventional gasoline on a well to wheels basis.[17]

Diesel-powered engines, due to the efficiency of the compression ignition engine and the higher energy content of the fuel, typically deliver between 10

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[14] Carbon dioxide, nitrous oxide, and methane

[15] World LP Gas Association, LP Gas – Helping Solve the Climate Change Problem, An executive Summary of LP Gas Solutions for Climate Change.

[16] Center for Clean Air Policy, Greg Dierkers, Senior Policy Analyst, Briefing to Interested California Stakeholders – April 6, 2005

[17] World LP Gas Association – LP Gas and Climate Change: Targeting the Switch to a Cleaner Fuel, Executive Summary

and 20 % fewer GHG emissions than comparable gasoline vehicles.[18] While the GHG emission performance is attractive, diesel engines emit considerably more particulate emissions than gasoline or propane vehicles.

Natural gas, similar to propane, produces fewer toxic and carcinogenic emissions than gasoline and diesel and virtually no particulate emissions.[19] According to the US Environmental Protection Agency, versus gasoline, life-cycle GHG emissions are reduced by 28.5% for Compressed Natural Gas and 22.6% for Liquefied Natural Gas (due to greater energy inputs).[20]

Ethanol, blended with gasoline in blend ranges from E5 (5% ethanol) to E85 (85% ethanol) is being implemented to reduce the impact of gasoline engine emissions. The U.S. Environmental Protection Agency states that for every BTU of gasoline that is replaced by corn-based ethanol, the total life-cycle Greenhouse Gas emissions that would have been produced from that BTU of gasoline would be reduced by 21.8%.[21] According to Environment Canada, E10 will produce about 3-4% fewer emissions than gasoline by itself.[22]

While the utilization of ethanol-blends results in tailpipe Greenhouse Gas reductions, some of these benefits are eradicated during production. Costs of fuel, typically natural gas, used in the production of ethanol are the second largest expense after the cost for corn feedstock. Increasing natural gas prices have forced ethanol plant owners to explore ways to reduce plant energy costs. Some owners have considered using coal as a less expensive process fuel, but that decision can significantly increase the GHG emissions on a wells-to-wheels evaluation.[23]

4.2.2 Propane emits significantly less criteria air contaminants and air toxics than conventional gasoline or diesel, reducing the negative impact on air quality and human health.

The environmental advantages of using propane over conventional or other alternative fuels are even more significant if unregulated emissions, some of which can be toxic, are taken into consideration.

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[18] Diesel Technology Forum – Energy Efficiency, Energy Independence & Greenhouse Gas Emission Reductions – www.dieselforum.org

[19] www.naturalgas.org/environment/naturalgas

[20] US Environmental Protection Agency – Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use – EPA 420-F-07-035 April 2007

[21] US Environmental Protection Agency – Greenhouse Gas Impacts of Expanded Renewable and Alternative Fuels Use – EPA 420-F-07-035 April 2007

[22] Environment Canada – www.ec.gc.ca/EnviroZine/english/issues/54

[23] Center for Transportation Research, Argonne National Laboratory – Life Cycle energy and Greenhouse Gas emission impacts of different corn ethanol plant types – Michael Wang, May Wu and Hong Huo – May 2007

It is commonly accepted that many of the substances emitted from the automobile tailpipe are considered to be harmful to human health. An analysis of transportation fuels must, therefore, include effects on human health in the immediate environment in which they are used. According to the California Air Resources Board (CARB), the substances listed below are among the most toxic substances emitted by vehicle exhausts:

- 1,3-butadiene;
- Formaldehyde;
- Benzene;
- Acetaldehyde; and
- Polycyclic organic matter (POM) associated with particulates.

CARB considers particulate matter from diesel engines to be the most carcinogenic substance, followed by 1,3-butadiene and benzene, respectively second and third on the board's list.[24] Table 3 below, illustrates the release of various toxic chemicals by select transportation fuels and highlights the relative cleanliness of propane. [25]

Table 3

Toxic chemicals in the air
All data in milligrams of chemicals/mile

	1,3-Butadiene	Formaldehyde	Benzene	Acetaldehyde
Conventional Gasoline	0.57	2.00	7.67	0.61
Diesel	0.58	1.65	4.72	0.56
Propane	0.11	1.68	0.63	0.43

Particulate matter (PM) and black carbon (BC) emissions from vehicle exhausts are also thought to contribute to climate change, though the extent of their contribution is being debated in the scientific community. Regardless of the status of the debate, human health concerns related to the carcinogenic nature of fine PM emissions have been the catalyst spurring legislation to lower PM emission tolerance levels for diesel and gasoline engines.

Numerous studies have shown that airborne particles (either solid or liquid) cause serious health problems. The US EPA has estimated that airborne particles cause over 15,000 premature deaths in the United States each year. In addition, scientists have found a correlation between exposure to airborne

[24] World LP Gas Association – LP Gas and Climate Change: Targeting the Switch to a Cleaner Fuel, page 27
[25] World LP Gas Association – LP Gas and Climate Change: Targeting the Switch to a Cleaner Fuel, page 28

particles and increased hospitalizations for asthma attacks, worsening of lung disease, chronic bronchitis, and heart damage. Furthermore, a March 2002 study suggests that airborne particles can cause lung cancer. In addition to these human health effects, particulate matter is the main cause of haze, which decreases visibility.[26]

In a report issued in June 2005, the Ontario Medical Association (OMA) estimated that air pollution would result in almost 5,800 premature deaths and 17,000 hospital admissions this year in Ontario alone. The OMA also estimates health care costs in 2005 at $507 million and total economic costs of air pollution at $7.8 billion.[27]

According to the Alternative Fuels Vehicle Institute (AFVI), as compared to conventional gasoline, the use of propane reduces particulate matter (PM_{10}) by 40%, nitrogen oxides by 50% and total hydrocarbon (THC) emissions by 87%.[28]

Although diesel-powered light vehicles emitted GHG's similar to those of propane-fuelled vehicles, diesel vehicles produced 30 times more PM.[29] Not surprisingly, school districts across North America have been among the earliest adopters to convert school buses from diesel to propane. They are driven by two facts: Propane is much cleaner than diesel (and therefore less harmful to the children who ride the buses on a daily basis); and propane cost savings amount to thousands of dollars per bus.

A study conducted by doctors and scientists from the University of California Berkeley School of Public Health, found evidence that diesel fumes not only are a major source of Greenhouse Gases, but also pose a significant public health risk.[30] Some of their more significant findings are as follows:

- *Diesel exhaust causes cancer and premature death and exacerbates asthma and other respiratory illnesses;*
- *A child riding inside of a diesel school bus may be exposed to as much as 4 times the level of toxic diesel exhaust as someone riding in a car ahead of it;*
- *Aside from its cancer-causing properties, diesel exhaust is also known to be a major source of fine particles, which can lodge deep in the lungs and exacerbate asthma, a condition most prevalent among children; and*

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[26] www.epa.gov/region5/air/naaqs/pm
[27] Ontario Ministry of Environment – Drive Clean Fact Sheet – November 18, 2005
[28] www.afvi.org/propane
[29] World LP Gas Association – LP Gas and Climate Change: Targeting the Switch to a Cleaner Fuel, Executive Summary
[30] "No Breathing in the Aisles: Diesel Exhaust Inside School Buses", Gina M. Solomon, M.D., M.P.H. Todd R. Campbell, M.E.S., M.P.P. Gail Ruderman Feuer, Julie Masters, Artineh Samkian, Kavita Ann Paul, *Contributor* Jesus Santos Guzman, M.D., M.S., January, 2001.

- *Over 40 individual chemical compounds in diesel exhaust have separately been listed as TACs. The EPA also identifies these chemicals as compounds that cause cancer.*

School boards have been aware of these health concerns for years and have been converting their school bus fleets to propane and saving millions of dollars in the process. The Northside Independent School District in North West San Antonio Texas is an example of a school board eliminating diesel-related health risks and saving taxpayer dollars by converting to propane.

4.3 Security of Fuel Supply

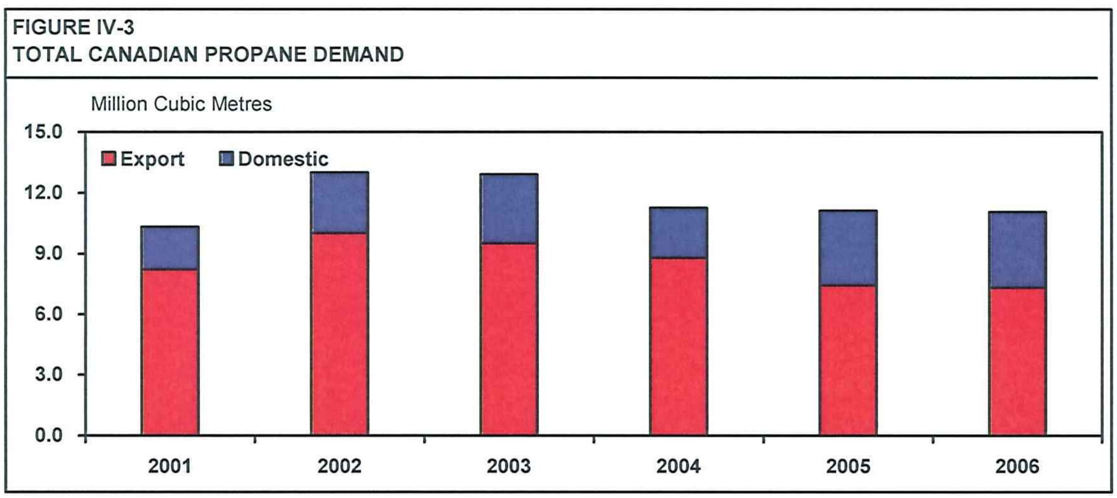
The research team concluded that:

"There is an abundance of propane in Canada available to meet the transportation sector needs. Propane from domestic sources could replace up to 20% of domestic gasoline demand"

4.3.1 Approximately 70% (8.6 Billion Litres) of Canada's annual production of propane is exported due to lack of domestic demand

Over the past five years, propane supply in Canada has averaged 11.9 billion litres, with domestic consumption averaging 3.3 billion litres, and exports averaging 8.6 billion litres, as shown on chart 3 below.[31] The Canadian and US retail demand is highly seasonal with demand peaking in the winter to meet the heating requirements of consumers and industrial/commercial customers.

Chart 3

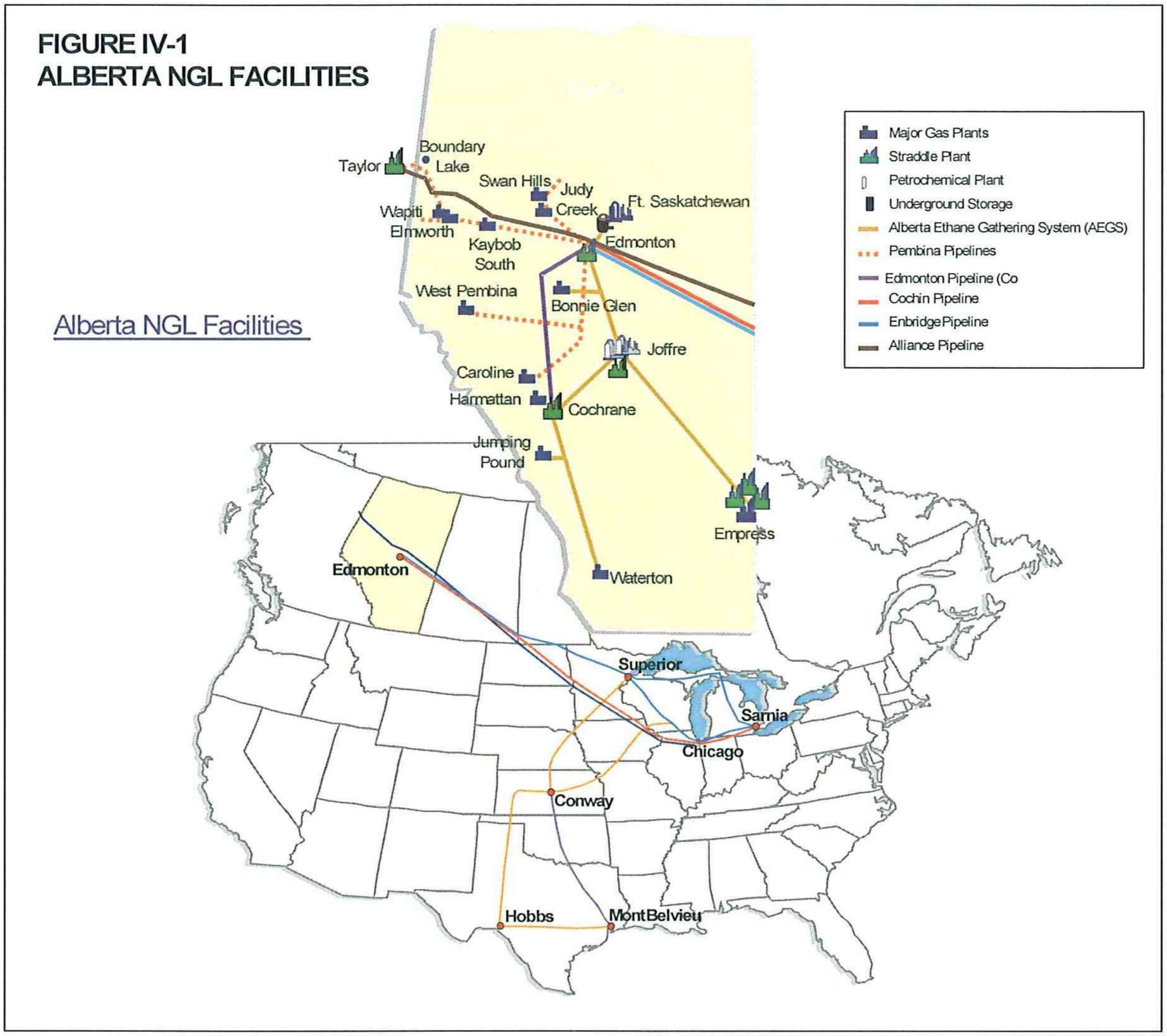


Canadian propane is supplied primarily by Alberta gas plant production, moved by pipeline, rail, and truck throughout the province, across Canada, and for export to the United States, as shown in Figure 1.[32] The excess supply produced in Canada is shipped to US markets and consumed in a variety of applications.

[31] Propane Market Study, prepared by Purvin and Gertz Inc. for the Propane Gas Association of Canada, published in April of 2007, Figure IV-3, page iv-7

[32] Propane Market Study, prepared by Purvin and Gertz Inc. for the Propane Gas Association of Canada, published in April of 2007, page iv-1

Figure 1



The existing Canadian propane transportation segment consumes approximately 300 million litres of propane, the equivalent of about 10% of overall domestic demand.[33] Researchers estimate that there are 50,000 to 60,000 propane vehicles operating in Canada today, in applications that consume a relatively low average consumption of 5,000 to 6,000 litres per vehicle per year.[34] Current marketplace utilization aside, the propane industry believes that the target market of high-consumption vehicles such as police fleets, taxi and limousines, couriers and delivery vehicles is ideally suited to use

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[33] Propane Market Study, prepared by Purvin and Gertz Inc. for the Propane Gas Association of Canada, published in April of 2007, Table IV-5, page IV-9
[34] Propane Market Study, prepared by Purvin and Gertz Inc. for the Propane Gas Association of Canada, published in April of 2007, page IV-13

propane as a transportation fuel. Typically, these vehicles consume 15,000 to 20,000 litres of propane per year depending upon their application. This potential target market could be another 60,000 vehicles.[35] With an average consumption of 20,000 litres per vehicle, additional demand could be 1.2 billion litres per year, the equivalent of approximately 10% of total propane supply in Canada.

This rise in demand can be met with existing and future Canadian supplies of propane, without disruption to the marketplace. Unlike domestic and export retail demand, which is highly seasonal with a high winter to summer usage ratio, transportation demand is constant year round, generating stable monthly volumes for the benefit of producers and transporters alike. Stable winter to summer volumes will allow industry players to capture distribution efficiencies not possible with high winter to summer ratios.

4.3.2 As existing North American petroleum refinery capacity is nearing 100% utilization, gasoline and diesel supply disruptions will continue into the foreseeable future, and the petroleum industry will face growing challenges to meet demand.

Crude oil is the primary input into the petroleum refining industry, satisfying the demand for gasoline and diesel fuel. Canada is a large and growing net exporter of crude oil and refined products, primarily serving the neighbouring United States market.

Imported crude oil satisfies more than half of the Canadian refinery demand. The higher costs to ship western Canadian crude to the eastern regions in which it is consumed make it more economically viable for some Eastern Canadian refineries to use imported crude oil. Accordingly, refineries in Western Canada use primarily domestic crude, Ontario refiners run a mix of domestic and imported crude oil and Quebec and Maritime refiners run primarily imported crude oil.[36]

There are 12 companies operating 19 refineries in Canada. Only Imperial Oil, Shell and Petro-Canada operate more than one refinery and market products nationally. Of the 19 refineries, 16 of the refineries manufacture a full slate of products. There are three main refining centres in Canada – Edmonton, Sarnia and Montreal.

In the early 1970's there were 40 refineries in Canada. Surplus operating capacities forced the less efficient and smaller refineries to close. The last refinery to close was the Petro-Canada refinery in Oakville, Ontario in 2005. No new refineries have been built in Canada since the early 1980's, although

[35] C2 Certus Corporation, Assessment of Market for Propane as a Transportation Fuel, 2007
[36] NRCan – http://fuelfocus.nrcan.gc.ca/reports/205-07/overview/index_e.cfm - Overview of the Canadian Downstream Petroleum Industry – page 2

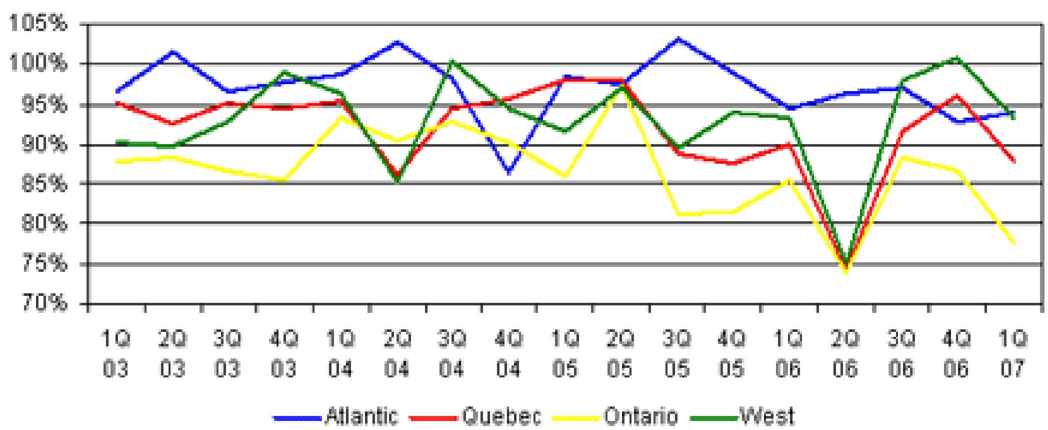
numerous refineries have been upgraded to meet environmental requirements and increased capacity requirements. Recently growth in demand has increased refinery utilization rates to over 90%.[37]

With North American refinery capacity utilization nearing 100%, the aggregate refinery capacity in North America limits the supply of refined product.[38] Lack of flexibility in refining capacity creates an environment where minor disruptions in refinery output can lead very quickly to supply issues in certain markets. This scenario was evident in the winter of 2007 in Ontario, where refinery production issues resulted in unprecedented gasoline and diesel shortages in a number of retail locations across the Province. During 2005, the hurricanes, Katrina and Rita, disrupted refinery production on the US Gulf Coast. The effects of these refinery disruptions were felt throughout North America. Supply and demand in Western Canada remains tight, as refineries have been operating at near full capacity for years.

Figure 2 below illustrates refinery utilization rates regionally since 2003. High utilization rates across North America have reduced the flexibility and ability of the refining system to respond to unexpected supply disruptions and have substantially increased the volatility of petroleum product prices.[39]

Figure 2

Refinery Utilization Rates



As existing North American refinery capacity is nearing 100% utilization, gasoline and diesel supply disruptions will continue into the foreseeable future, and the industry will face growing challenges to meet demand**.** Refinery

[37] – http://fuelfocus.nrcan.gc.ca/reports/205-07/overview/index_e.cfm - Overview of the Canadian Downstream Petroleum Industry – pages 3 to 8

[38] Canadian Petroleum Products Institute, Website publication, Petroleum Markets, Understanding their Dynamics, The Continental Market for Refined Products Section

[39] NRCan – http://fuelfocus.nrcan.gc.ca/reports/2007-06/rates_e.cfm

expansion is planned for Sarnia and an additional refinery is planned for Atlantic Canada (primarily for the US market) but these projects will take years to implement from the planning and permit stage to full operation.

4.3.3 While Canada is enviably positioned to meet domestic natural gas demand, supply and price volatility within the North American market will result from increasing US natural gas demand coupled with shrinking US domestic supplies.

Regional Canadian and US natural gas commodity markets are well connected by natural gas pipelines. This infrastructure allows supply and demand fundamentals to be transferred across all markets. Natural gas prices in Canada and the US track each other. Canada and the US are often described as being an integrated continental natural gas market.[40]

Canadian natural gas production levels exceed domestic gas consumption. In 2005, Canada produced 16.5 billion cubic feet per day (bcf/d) of marketable natural gas. Approximately 45% was consumed domestically with the remaining 55% exported to the United States. The US consumes more natural gas than it produces, and thus imports natural gas to satisfy its production deficit. The US imports natural gas from Canada by pipeline, and from other countries via large ocean tankers that carry liquefied natural gas (LNG). The US obtains roughly 16% of its natural gas supply from Canada and 3% from other countries via LNG imports.[41] There are currently five operating import LNG terminals in North America, all located in the United States.

The potential for natural gas supply disruptions caused by the US Gulf coast hurricane season is similar to crude oil disruptions. During 2005, the hurricanes, Katrina and Rita, were able to disrupt approximately 90% of the US offshore production of natural gas, and consequently create significant price spikes.[42]

Between 1986 and 2001, Canadian natural gas production grew steadily, more than doubling from 7.0 bcf/d to 16.6 bcf/d. Since 2001, however, production from Western Canada has flattened out despite high levels of drilling activity. Over time, producers have found and drilled the largest and highest-quality reservoirs first. Now, finding new natural gas involves drilling into smaller and lower quality reservoirs. More and more new wells are thus needed in order to replace old wells, which have declined, and increases in production come about more slowly. The situation is similar in the US. While natural gas production is

[40] Natural Resources Canada, Natural Gas Division, Energy policy Sector – Canadian Natural Gas 2006-07 Outlook, November 2006

[41] Natural Resources Canada, Natural Gas Division, Energy policy Sector – Canadian Natural Gas 2006-07 Outlook, November 2006

[42] Canadian Natural Gas, Review of 2005 & Outlook to 2020, published by Natural Gas Division, Petroleum Resources Branch, Energy Policy Sector, Natural Resources Canada, Page iii of the Executive Summary

essentially flat, natural gas demand continues to grow steadily, due to the clean burning nature and overall attractiveness of natural gas as a fuel for homes, businesses, industries, and electric power stations.[43]

Underground and liquefied natural gas storage allows companies to stockpile natural gas supplies for use during winter, when demand is at its peak. The amount of available natural gas in storage affects natural gas prices and deliverability. Low storage levels offer a smaller supply cushion during periods of peak demand and consequently, contribute to price uncertainty.

Canadian natural gas production is forecast to be the same in 2020 as in 2005: approximately 6 trillion cubic feet (TCF) per year. Coal bed methane production is expected to increase in Canada becoming increasingly important to the Canadian natural gas production mix. The US, however, is facing the continuous decline of natural gas production in spite of the increase in the number of wells drilled in the last few years. Contrary to the situation faced by Canadians, the US natural gas domestic supply is expected to continue declining even when demand seems to be growing. Mexico faces similar challenges to the US with declining domestic supply and increasing domestic demand. Overall the North American picture is one where demand exceeds supply, and imports from overseas are increasing. To ensure the development of their own natural gas deposits, the US and Mexico must face significant challenges including environmental issues, political willingness, political support, and governmental policies. In contrast, Canada faces fewer challenges in developing its conventional and non-conventional resources.[44]

In order to meet future demand, natural gas supplies for North America will come from a broad range of LNG suppliers outside of North America. To ease the increasing demand for natural gas for electricity generation, the US may increasingly turn to clean coal and nuclear alternatives. There are over 40 proposed LNG import terminals in North America, primarily in the U.S. Many of the proposed terminals that are located closer to major markets face significant regulatory and environmental hurdles. Canada is looking at LNG in a relatively small way to service coastal and export markets, rather than for broad domestic Canadian use. Energy projections suggest that Canada does not need to develop LNG in order to meet its future electricity and other demands.[45] A number of projects have been proposed to construct LNG import facilities in Canada and three projects on the east and west coasts (Canaport LNG, Bear Head LNG, and Kitimat LNG) have received Federal-Provincial regulatory approval. Two LNG projects in the Quebec City area (Rabaska and Gros-Cacouna) have been approved by the Quebec and Federal Governments;

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[43] Natural Resources Canada, Natural Gas Division, Energy policy Sector – Canadian Natural Gas 2006-07 Outlook, November 2006

[44] North American Energy Working Group (NAEWG) – Natural Gas Workshop – Workshop Report – June 28,2006 –page 3

[45] North American Energy Working Group (NAEWG) – Natural Gas Workshop – Workshop Report – June 28,2006 – page 6

however the Gros-Cacouna project has been delayed to 2012 due to rising project costs.

It is clear that additional pipeline infrastructure will be required to meet rising future demand for natural gas in North America. Pipeline costs are going up and there is a shortage of both labour and materials to expand Canadian and North American natural gas transmission infrastructure. These challenges, manifesting themselves in construction delays and increasing infrastructure costs, will have an inflationary affect on the price consumer's pay in Canada and more broadly, in the North American market.

Environmental regulations, inefficient agency coordination, and the lack of measures to reduce costs directly, were the most common factors identified as causes of pipeline construction delay and cost escalation in North America.[46] While Canada should be enviably positioned to meet domestic demand, supply and price volatility within the North American market will exist primarily due to US increasing demand with shrinking US domestic supplies.

4.3.4 While the estimated Canadian demand for Ethanol is 2.0 Billion litres annually, current Canadian capacity, including capacity under construction is estimated to be approximately 1.7 Billion litres.

The continued growth of the ethanol industry and the long-term market potential for ethanol depends upon the resolution of critical issues that influence the supply and demand for ethanol. Resolution of technical, economic, and regulatory issues remains critical to further development of ethanol in the United States and in North America.[47]

It is estimated that 2.0 billion litres of ethanol per year will be required to meet current Canadian Provincial and Federal mandates using domestic resources. Currently there is approximately 1.7 billion litres of capacity in place or under construction in Canada.

Ethanol and ethanol-blended gasoline, because of its ability to pick up water, cannot be transported by pipeline. Ethanol can be shipped by railcar or truck; but it must be blended at the terminal. Dedicated tanks are required to store ethanol and the gasoline-blending component with which it will be mixed. The handling of ethanol-blended fuels also requires modifications to the other aspects of the fuel-distribution system, including trucks, retail storage tanks and service station pumps.

[46] North American Energy Working Group (NAEWG) – Natural Gas Workshop – Workshop Report – June 28,2006 – page 7
[47] Energy Information Administration – Biofuels in the US Transportation Sector – Originally published in the Annual Energy Outlook 2007, February 2007, Washington, DC.

Canada is a net corn and feed wheat importer as well as being a net importer of ethanol. Additional ethanol production infrastructure is being developed with support from the Federal Ethanol Expansion Program and support from Provincial Governments in Alberta, Saskatchewan, Manitoba and Ontario. Currently Canadian ethanol production is approximately 700 million litres annually (Table 4)[48] with additional production coming on stream in 2007 and 2008(Table 5).[49]

Table 4

2006 Canadian Ethanol Production

Company	Location	Annual Production
Permolex	Red Deer, Ab.	40 million litres
Husky Energy	Lloydminster, Sask.	130 million litres
Poundmaker	Lanigan, Sask.	12 million litres
NorAmera Bioenergy	Weyburn, Sask.	25 million litres
Husky Energy	Minnedosa, Man.	10 million litres
Iogen	Ottawa, Ont.	2 million litres
Greenfield Ethanol	Chatham, Ont.	150 million litres
Greenfield Ethanol	Tiverton, Ont.	26 million litres
Suncor	Sarnia, Ont.	200 million litres
Greenfield Ethanol	Varennes, Que.	120 million litres

Table 5

Ethanol Production Additions for 2007 and 2008

Company	Location	Annual Production	Date
Terra Grain Fuels	Belle Plain, Sask.	150 million litres	2007
Collingwood Ethanol	Collingwood, On.	52 million litres	2007
Husky Energy	Minnedosa, Man.	130 million litres	2007
Greenfield Ethanol	Hensall, Ont.	200 million litres	2008
Greenfield Ethanol	Johnstown, Ont.	200 million litres	2008
Integrated Grain Processors	Aylmer, Ont.	150 million litres	2008

Until there is greater market penetration, and until demand is more developed under the Government mandates, it will be difficult to predict the security of ethanol supply using current technology. Factors affecting supply will include: tightness in the supply and demand markets for crops; yields affected by weather; crop competition; input energy costs affecting ethanol production costs; US ethanol market dynamics; and the development of new technology.

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[48] Canadian Renewable Fuels Association – Plant Locations – September 2007
[49] Canadian Renewable Fuels Association – Plant Locations – September 2007

4.4 Fuel Price Stability

The research team concluded that:

"Propane pricing has been, and is likely to be, more stable than gasoline, diesel, and ethanol-blends well into the future"

4.4.1 Propane prices should continue to prevail at levels well below that of gasoline, even if domestic propane demand rises sharply.

Energy pricing reacts rapidly to changes in the underlying supply and demand of the fuel. When supply outstrips demand, prices face downward pressure and vice-versa. As a fleet operator, stability of fuel pricing is important to the operation and budgeting of the fleet.

The Canadian propane production infrastructure is well developed, and supplies with ease the domestic demand as well as the export requirements.[50] There are not any foreseeable delivery capacity issues within Canada that would significantly, over a long period of time, adversely affect the supply/demand balance.

Approximately 85% of Canadian propane production results as a by-product of the production of Canadian natural gas for the North American marketplace, with the remainder produced as a by-product of crude oil refining.[51] According to a study conducted by Purvin and Gertz, over the past five years, propane supply in Canada has averaged 11.9 billion litres, with domestic consumption averaging 3.3 billion litres, and exports averaging 8.6 billion litres.[52]

This excess supply position of Canadian-produced propane acts to damper the volatility of propane pricing over time. Monthly, Canadian propane producers must "place/sell" their production that results from natural gas and crude refining activities. Storage capabilities are limited in relation to the size of the production. In addition to the well-recognized uses of propane, such as heating, cooking, and transportation fuel, a large amount of propane is consumed by the North American petrochemical sector, as a process component. To market their supply of propane successfully, Canadian producers must ensure pricing is competitive with the other alternatives that are available to this sector (e.g. ethane, butane and naphtha).

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[50] Propane Market Study, prepared by Purvin and Gertz Inc. for the Propane Gas Association of Canada, published in April of 2007, Executive Summary, page iv-i

[51] Propane Market Study, prepared by Purvin and Gertz Inc. for the Propane Gas Association of Canada, published in April of 2007, Executive Summary, page iv-6

[52] Propane Market Study, prepared by Purvin and Gertz Inc. for the Propane Gas Association of Canada, published in April of 2007, Figure IV-3, page iv-7

Using a wider perspective than Canada, there are multiple international sources of propane available to the US market, and the world currently has an excess of supply. Should demand for propane rise substantially in Canada due to the increased demand as a transportation fuel, it is unlikely that pricing would be significantly affected due to the ability of the excess supply to absorb demand increases, and the ability of the industrial complex to choose alternative input feed stocks. Propane, along with other alternative fuels, enjoys excise tax relief at the Federal Government level and in some provinces, has road tax reductions relative to gasoline.

4.4.2 Propane prices are more stable than gasoline prices and are expected to continue their pricing behaviour into the foreseeable future

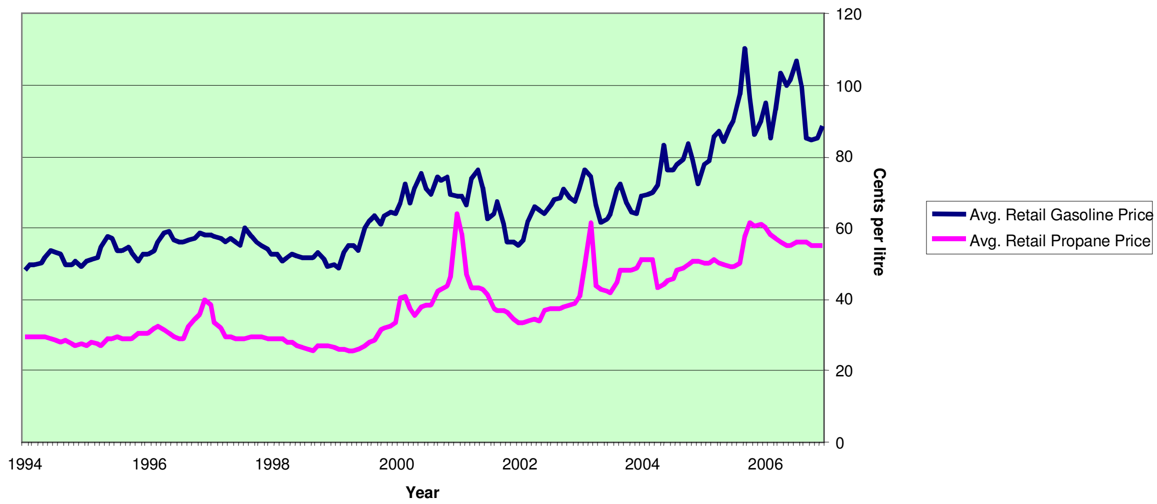
Retail pricing for propane is based on its wholesale price, as set by the producers, plus transportation costs, and a margin for the propane marketers. Federal and provincial taxes are added as applicable. In most cases, propane prices at the retail level do not exhibit the day-to-day price volatility that is evident with gasoline and diesel prices.

As shown in Chart 4, the price of propane in Ontario over the last 12 years has been consistently about 40% lower than gasoline.[53] The chart also reveals that, while there have been a number of propane price spikes over the years; overall, propane has experienced less price volatility than gasoline. It is anticipated that this historical price gap between gasoline and propane will continue due to the combination of the limited North American gasoline refining capacity and world demand for crude oil contrasted against the excess supply of Canadian-produced and world-produced propane.

[53] Ontario Ministry of Energy – Historical Fuel Prices – www.energy.gov.on.ca - Prices for regular unleaded gasoline and propane for Southern Ontario

Chart 4

Historical Gasoline and Propane Pricing Ontario



4.4.3 Gasoline, Gasoline/Ethanol blends, and Diesel Fuel pricing will continue to be volatile

The pricing for refined gasoline, gasoline/ethanol blends, and diesel fuel is driven by supply and demand for both raw materials components (crude oil) and for the finished products themselves. Crude prices are driven by new and rising demand from developing nations, demand resulting from strong economic performance of developed nations, and from various factors affecting the uncertainty of the supply.

As world demand strains crude oil supply capacity, crude pricing escalates significantly.[54] Contributing to the uncertainty and sensitivity of crude oil pricing is the fact that a significant percentage of crude oil supply lies in politically unstable regions. Furthermore, OPEC, with 12 members, controls 40% of the world's crude oil production, and 75% of the world's known oil reserves.[55]

Even with modernization, upgrades and improvements, North American refinery capacity utilization rates are near 100%.[56] Finished product supply disruptions can be caused by many factors including the weather and the lack of spare international refining capacity. In addition, seasonal fluctuations in demand can create significant pricing fluctuations.

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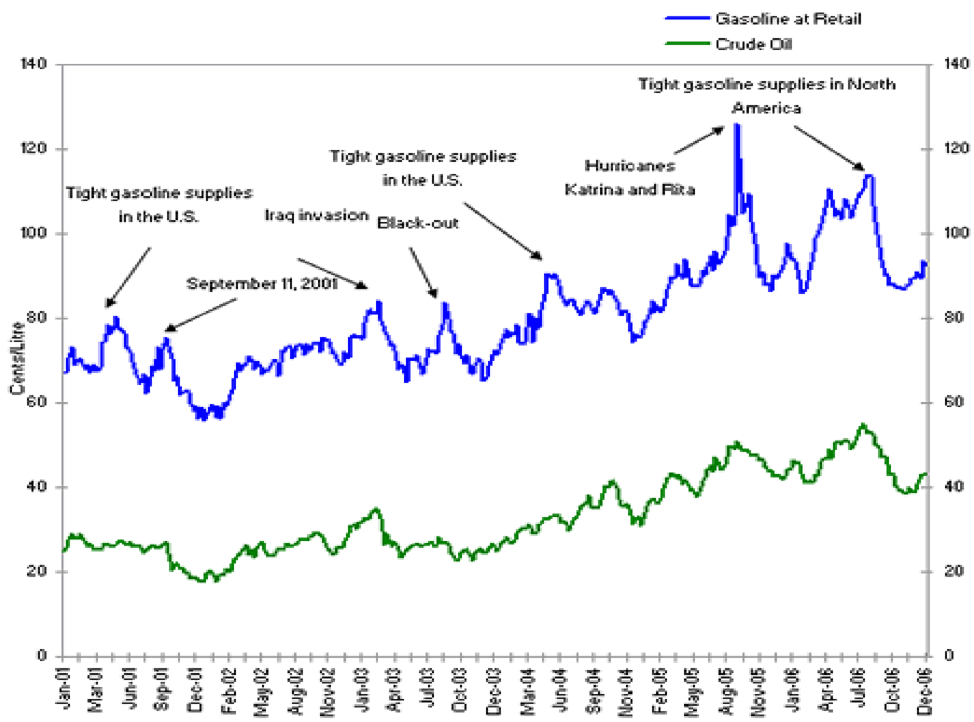
[54] Canadian Petroleum Products Institute, Website publication, Petroleum Markets, Understanding their Dynamics, Lack of Excess Production Capacity Pushes World Crude Oil Prices Upward Section
[55] Canadian Petroleum Products Institute, Website publication, Petroleum Markets, Understanding their Dynamics, International Market for Crude Oil Section
[56] Canadian Petroleum Products Institute, Website publication, Petroleum Markets, Understanding their Dynamics, The Continental Market for Refined Products Section

Chart 5, from Natural Resources Canada, illustrates the historical relationship between crude oil and gasoline prices over the last five years in Canada, and notes the major price disruptions that have occurred in North America [57]. It is anticipated that the gasoline market will remain volatile for the foreseeable future, as the timelines to develop additional refining capacity from approvals to start-up are significant.

Chart 5

Historical Relationship between Crude Oil and Gasoline Prices



With respect to gasoline blended with ethanol, the price volatility factors remain similar to conventional gasoline. Crude input costs combined with refinery capacity issues concerning both gasoline feedstock and the supply of ethanol for blending are significant influences. Historically, in the United States, the wholesale price differential between convention unleaded gasoline and E85 has been between 35 and 80 cents per gallon.[58] Prices for ethanol and unleaded gasoline are relatively volatile and appear to follow similar patterns. Chart 6, shown below, is supplied by the California Energy Commission and shows that fuel ethanol prices in the United States have been volatile over the past 10 years.[59]

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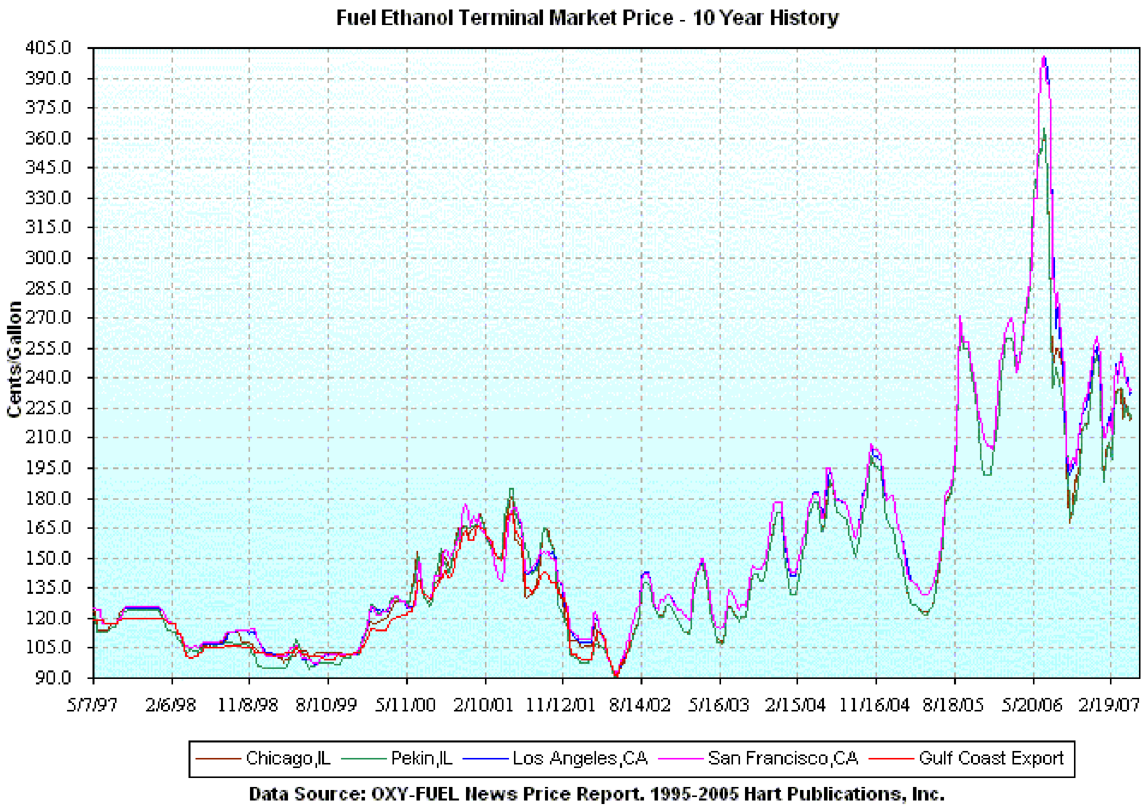
[57] Natural Resources Canada website – http://fuelfocus.nrcan.gc.ca/fact sheets/timeline e.cfm
[58] Ohio Corn Growers Association – www.ohiocorn.org/ethanolgaspoints.html
[59] California Energy Commission – www.energy.ca.gov/gasoline/graphs/ethanol_10-year.html

Chart 6



4.4.4 In spite of differing factors affecting supply and demand, the long-term trend for natural gas pricing is higher and its pricing stability is linked to the stability of crude oil

A recent report on the "Outlook for Canadian Natural Gas until 2020" published by Natural Resources Canada suggests that, in spite of differing factors affecting supply and demand, the long-term trend for natural gas pricing is higher. Increasingly, the North American market is being influenced by factors in other markets.[60] For example, liquefied natural gas (LNG) is expected to become the next major continental fuel source. Numerous natural gas storage and delivery facilities are being built in Canada and the United States. Additionally, Natural Resources Canada explores the pricing link between the price of natural gas and the price of crude, highlighting the capability of industrial oil products users to shift demand to natural gas as pricing differentials escalate, moderating oil pricing and putting upward pressure on the prices of natural gas.[61] Chart 7 below illustrates the relationship between crude

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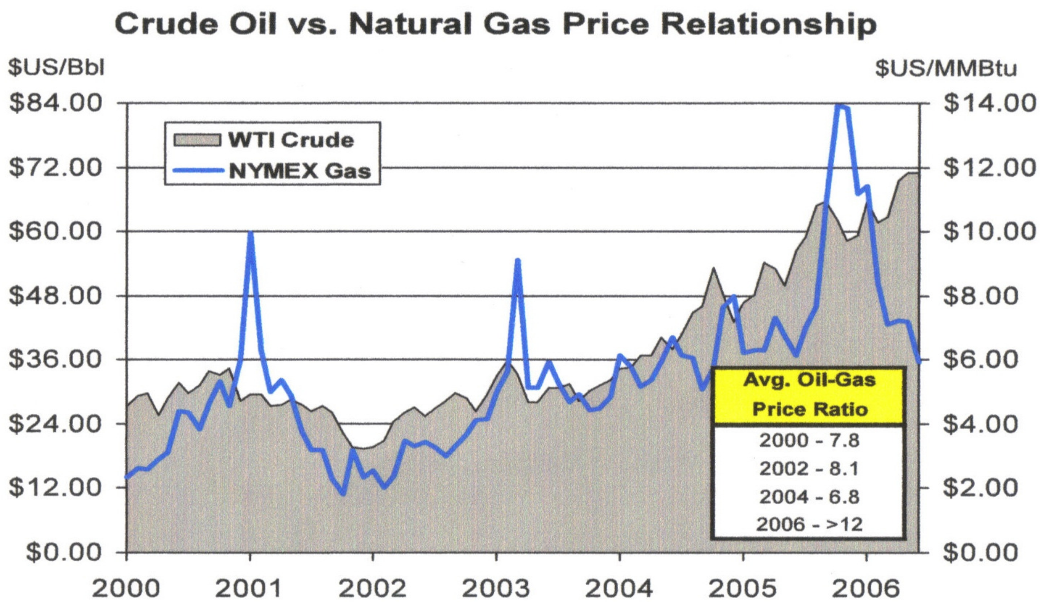
[60] Canadian Natural Gas, Review of 2005 & Outlook to 2020, published by Natural Gas Division, Petroleum Resources Branch, Energy Policy Sector, Natural Resources Canada, Page iii
[61] Canadian Natural Gas, Review of 2005 & Outlook to 2020, published by Natural Gas Division, Petroleum Resources Branch, Energy Policy Sector, Natural Resources Canada, Page 29, Figures 28 and 29

oil prices and natural gas prices since 2000. Elevated natural gas levels have driven down the price of natural gas in 2006-07. As natural gas supply levels are depleted, however, it is expected that the historical relationship between crude and natural gas will be restored.[62]

Chart 7



Similar to crude, natural gas faces the potential for supply disruptions caused by the U.S. Gulf coast hurricane season. During 2005, the hurricanes, Katrina and Rita, shut down approximately 90% of the US offshore production of natural gas, significantly increasing pricing during the disruptions.[63] In fact, natural gas commodity prices reached a record level in 2005, with Intra-Alberta prices 25% higher than 2004 and 70% higher than 2000.[64]

It is estimated that North American natural gas demand will grow from 25.8 trillions of cubic feet (Tcf) in 2005 to about 31 Tcf in 2020. Much of the growth is pegged to increased demand in the Canadian (Alberta) industrial sector, and both the United States and Canadian power generation sectors as shown in Chart 8.[65]

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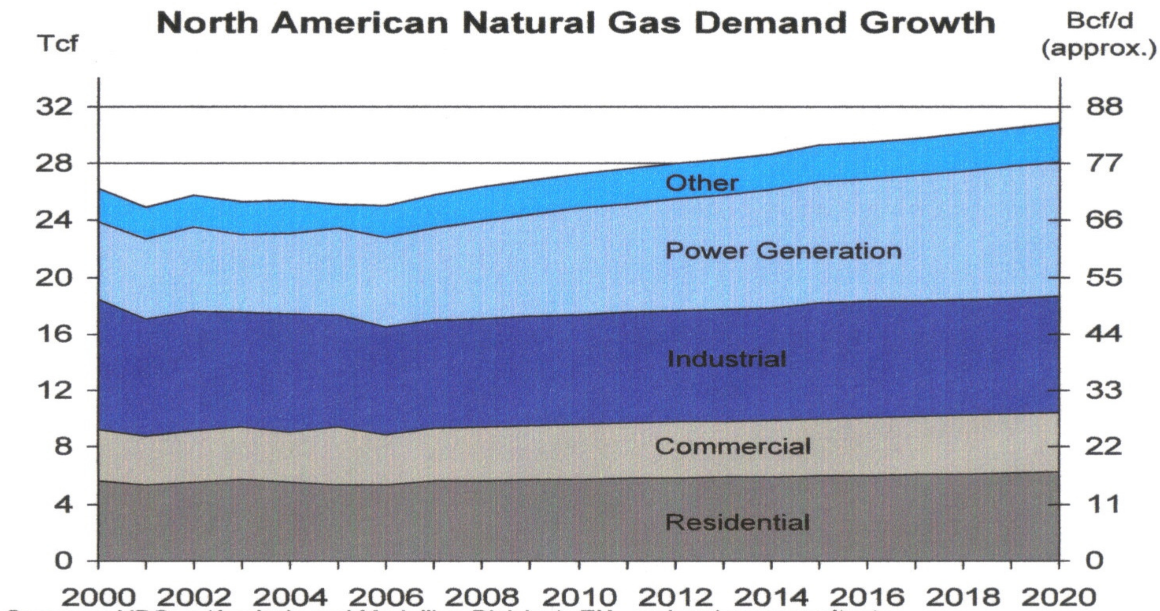
[62] Canadian Natural Gas, Review of 2005 & Outlook to 2020, published by Natural Gas Division, Petroleum Resources Branch, Energy Policy Sector, Natural Resources Canada, Page 29
[63] Canadian Natural Gas, Review of 2005 & Outlook to 2020, published by Natural Gas Division, Petroleum Resources Branch, Energy Policy Sector, Natural Resources Canada, Page iii of the Executive Summary
[64] Canadian Natural Gas Winter 2006-07 Outlook, published November 2006 by Natural Gas Division, Petroleum Resources Branch, Energy Policy Sector, Page 2
[65] Canadian Natural Gas, Review of 2005 & Outlook to 2020, published by Natural Gas Division, Petroleum Resources Branch, Energy Policy Sector, Natural Resources Canada, Page 40, Figures 35 & 36

Chart 8



Sources: NRCan (Analysis and Modelling Division), EIA, and various consultants.
Notes: (1) Represents an average or "consensus" view of forecasts of various organizations.
(2) Historical numbers from EIA and StatsCan.

Natural Resources Canada forecasts natural gas prices to be above $7.50/GJ for the next three years and averaging $7.36 by 2015. The forecast is for natural gas prices to be in the $8.00 to $10.00/GJ range by 2020.[66] These forecasts do not take into account supply disruptions such as hurricanes and other world events. Historically, natural gas prices have been volatile and it is anticipated that this will continue as increased demand stresses sources of supply.

[66] Canadian Natural Gas, Review of 2005 & Outlook to 2020, published by Natural Gas Division, Petroleum Resources Branch, Energy Policy Sector, Natural Resources Canada, Page 52, Figure 52

4.5 Fuelling Infrastructure

The research team concluded that:

"Propane is the most readily accessible and available alternative fuel in Canada, and additional infrastructure is easily installed as fleet-specific needs arise"

4.5.1 A well established network of pipelines, storage, distribution points, and approximately 2,500 retail locations, combined with the relative ease of installation of new refuelling infrastructure will enable propane to respond to customer demand in the transportation sector.

Most of the propane in Canada is produced in Western Canada. A system of pipelines delivers propane and other natural gas liquids to Sarnia, Ontario. An extensive network of rail and road transportation serves the Ontario and Eastern markets. There are over 300 distribution points in Canada that can be readily expanded.

Currently, approximately 2,200 to 2,500 retail sites across Canada dispense propane to vehicles.[67] These stations are primarily located in urban centres in Ontario, British Columbia and Alberta – the remnants of a network of over 5,000 stations that were in place until the early 1990's. In addition there are private refuelling stations serving dedicated fleets with vehicles running on propane.

Propane refuelling locations are relatively easy to install and usually leverage existing gasoline refuelling sites. The space requirements are nominal and tanks are typically installed aboveground. There are no environmental issues associated with the installations and a well-developed set of codes and regulations exist to govern the storage and handling of the product. Capital expenditures for smaller self-contained dispensing stations for fleets start at about $25,000. A typical retail site consisting of a 15,000 litre tank and dispensing for about 100 or more vehicles per day costs approximately $75,000.

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[67] Propane Market Study, prepared by Purvin and Gertz Inc. for the Propane Gas Association of Canada, published in April of 2007, page IV-13

Table 6 below shows the number of fuelling stations, by fuel type, available to the public in Canada.

Table 6

Number of retail fuelling stations available to the public in Canada

	# of stations in Canada	
Gasoline	14,000[68]	
Diesel	6,300[69]	(primarily at gasoline stations)
Propane	2,200 to 2,500[70]	
CNG	100	
Ethanol – E85	3	All located in Ontario
Biodiesel (100%)	0	Approximately 25 retail sites offering biodiesel blends
Methanol	0	
Hydrogen	3	Under development as part of the hydrogen highway in BC

4.5.2 Ethanol E10 availability at the retail level is growing rapidly, supported by ease of implementation and government regulation, but E85 refuelling infrastructure is virtually non-existent in Canada.

According to available Government data, there are about 1,000 retail outlets in Canada selling ethanol-blended gasoline.[71] The Federal Government introduced regulations in its 2007 budget requiring 5% renewable content in total gasoline sales and 2% content in total diesel fuel sales by 2010. Ontario introduced a Renewable Fuels Standard effective January 1, 2007 requiring gasoline to contain an average of 5% ethanol. Effectively, this legislation will place E5 or E10 at virtually every location currently dispensing conventional gasoline within Ontario, and will accomplish the same in other provinces that begin to adopt ethanol-blend fuels.

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[68] M.J. Ervin & Associates Inc. – National Retail Gasoline Site Census - 2004
[69] M.J. Ervin & Associates Inc. – National Retail Gasoline Site Census - 2004
[70] Purvin Gertz Inc. – Propane Market Study prepared for Propane Gas Association of Canada – April 2007
[71] http://oee.nrcan.gc.ca/publications/infosource/pub/vehiclefuels/ethanol/M92_257_2003.cfm -

E85 is currently not mandated. There are only three retail sites offering E85 ethanol-blends in Canada; one located in Ottawa and two located in South-Western Ontario. E85 dispensing facilities can be located at existing service stations, however additional dispensers and underground tanks would be required to store and dispense the product. The estimated cost of an installation would be approximately $60,000, depending upon the site and configuration. Natural Resources Canada states "significant changes will be needed in Canada's fuel distribution and dispensing infrastructure to accommodate high-level ethanol-blends."[72]

4.5.3 The high cost of implementation has limited the development of natural gas refuelling infrastructure across Canada, with regional representation in Ontario, British Columbia, and Alberta totalling 100 sites nationally.

There are approximately 100 retail CNG refuelling sites across Canada. Ontario has approximately 35 sites, with the balance primarily located in mainland British Columbia and the Calgary to Edmonton corridor.

Retail natural gas-refuelling sites can often be integrated with existing gasoline stations, however the space requirement for the compressor station and storage systems often preclude installation at smaller or congested sites. Natural gas fuelling stations range in capital cost from $250,000 to $2,000,000 for infrastructure. Additional costs may be required to upgrade distribution pipelines for sufficient pressure and volumes to serve the station's demand.

[72] http://oee.nrcan.gc.ca/publications/infosource/pub/vehiclefuels/ethanol/M92_257_2003.cfm - accessed 28 October 2007

4.6 Public and Private Sector Implications

The research team concluded that:

"Propane as a transportation fuel is ideally positioned to assist governments and the private sector with their efforts to address environmental issues."

4.6.1 Canada's environment continues to face challenges with respect to air quality, water quality, and Greenhouse Gas emissions

Canada's environment continues to face challenges with respect to air and water quality and Greenhouse Gas emissions, according to the third annual report of environmental sustainability indicators.[73] Greenhouse Gas emissions remained at nearly the same level in 2005 as in 2004, but are still significantly above 1990 levels and Canada's target under the Kyoto Protocol.

Total GHG emissions increased over the 1990 to 2005 period, due to increased economic activity. The indicator results are partly due to the growing Canadian population and economy. Between 1990 and 2005, Canada's population increased by 17% to 32.3 million. This increase, coupled with economic growth, led to greater resource use and waste production, increased GHG emissions and, in certain cases, more air and water pollution. Increasingly, public and media attention has focused on the environment. Governments and corporations are being forced to review and take steps to improve their environmental performance in general and specifically, to reduce their GHG emissions.

Air quality indicators track measures of Canadians' exposure to ground level ozone and fine particulate matter during the warm season (April 1 to September 30).[74] These pollutants are key components of smog and can lead to adverse health effects even at low concentrations in the air. The Canadian Environmental Sustainability Indicators report shows that the ozone exposure indicator has increased by an average of 0.8% per year between 1990 and 2005, translating into an overall increase of about 12% during that 15 year period. The report shows that the ozone exposure indicator increased primarily in Southern Ontario and in Southern Quebec over the period. The indicator level was unchanged in other regions.

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[73] The Daily page 1– October 15, 2007, Release based on highlights from the third annual report of the Canadian Environmental Sustainability Indicators, prepared by Environment Canada, Statistics Canada and Health Canada. A full report is scheduled for release in December 2007.

[74] The Daily page 2 – October 15, 2007, Release based on highlights from the third annual report of the Canadian Environmental Sustainability Indicators, prepared by Environment Canada, Statistics Canada and Health Canada. A full report is scheduled for release in December 2007.

4.6.2 Government Incentives target private citizen vehicles

Many of the incentives and initiatives at different government levels are targeted at private citizen's vehicles (and voters) to encourage purchases of lower consumption gasoline vehicles and hybrids. None of the programs are targeted at light-duty fleets with larger vehicles and higher gasoline consumption patterns. These fleets include police fleets, municipal service trucks and vans, taxis and limousines, courier and delivery vehicles, and service and repair vehicles. Many of these types of vehicles operate in urban centres and contribute significantly to GHG emissions and air pollution.

4.6.3 Federal Government

Recent polls and surveys have placed the environment at the top, or near the top, of voters' and consumers' agendas. In the recent Ontario election, although the Green Party did not garner any seats in the Legislature they did receive 8% of the popular vote. The current Canadian Federal Government did not initially have the environment on its agenda of key items to address. Under increased pressure from the public and media, however, the Federal Government has increasingly made the environment a more significant part of its agenda.

To date specific Canadian Federal Government programs include developing emissions regulations, investing in public transportation infrastructure, encouraging the use of public transportation, and offering incentives for low consumption gasoline and/or hybrid vehicles. In addition, the Government has mandated a 5% average renewable content in fuels requirement by 2010. The Federal Government has recently stated that Canada cannot meet the targets set under the Kyoto Accord.

The latest Treasury Board Report for fiscal 2005-06 examined Federal Government compliance with the *Alternative Fuels Act (1995)*. This act took effect April 1, 1997, and requires, where it is cost-effective and operationally feasible, that 75% of the vehicles operated by Federal departments and agencies use alternative transportation fuels. The Treasury Board Report indicated that no alternative-fuel powered vehicles were deemed operationally feasible and cost-effective in the Federal fleet at that time.[75] In fact, usage of alternative fuels in the Federal fleet has declined from historical levels. Propane and natural gas vehicles that were in the Federal fleet have been replaced due to age, and new flex fuel (E85) vehicles have been purchased. It is interesting to note that only 658,872 litres of E85[76] was purchased in 2005-06, while almost 60,000,000 litres of gasoline and diesel was purchased during the same time

[75] Treasury Board of Canada Secretariat, Annual Report to Parliament, Report on the Application of the *Alternative Fuels Act,* Fiscal Year 2005-06, page 1
[76] Treasury Board of Canada Secretariat, Annual Report to Parliament, Report on the Application of the *Alternative Fuels Act,* Fiscal Year 2005-06, page 3

period.

4.6.4 Ontario Government

While the Federal Government signed the Kyoto Protocol, the Provinces and Territories (collectively "the Provinces") are essentially responsible for delivering the climate change programs. The Provinces have jurisdiction over important sectors relating to energy and GHG emissions. The Provinces are directly responsible for managing Canada's natural resources, including oil, natural gas, and coal. The Provinces also have jurisdiction over electricity management. On a related note, Canada's electricity and oil and gas sectors are responsible for the largest increase in Greenhouse Gas emissions since 1990.

The Provinces also have sole responsibility in regulatory areas such as building codes, which are crucial to improving the energy efficiency of Canada's residential and commercial building stock. Finally, the Provinces have jurisdiction over Canada's Municipalities, where much of the on-the-ground emission reductions will have to happen.[77]

The Ontario Government has been developing an environmental agenda.[78] A Climate Change Plan was delivered for Ontario in August 2007, setting out specific targets for GHG emissions reductions.[79] The primary focus has been on eliminating coal-fired electricity generation and increasing hydro, wind and nuclear generation. In the transportation sector, incentives have been put into place to encourage hybrid vehicles (this is a popular initiative in many provinces) and lesser incentives remain for propane and natural gas vehicles.

Ontario is also encouraging energy conservation practices. Significant funds are being spent on public transit systems in municipalities within the Golden Horseshoe area, in an effort to improve services and ultimately, to increase ridership. The Province has also set up technology funds to encourage research and development into emerging energy sources to mitigate air pollution and climate change. Incentives are planned to encourage people to switch to greener vehicles[80] and plans are underway to introduce special eco-green licence plates. Road transportation (the fastest growing GHG emissions segment) has not been meaningfully addressed to date, other than the mandate of 5% average ethanol content in gasoline by 2007. The David Suzuki Foundation suggests Ontario residents would be better served with incentives to purchase fuel-efficient vehicles (and fees on gas guzzlers) rather than using ethanol fuels that have little or no climate-change benefits. (A recent David

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[77] David Suzuki Foundation – All over the Map: A comparison of provincial climate change plans - 2005
[78] Ontario Ministry of Environment – Fact Sheet dated June 26, 2006
[79] Go Green – Ontario's Action Plan on Climate Change – August 2007
[80] Go Green – Ontario's Action Plan on Climate Change – August 2007 page 12

Suzuki Foundation study found that a 10% ethanol-blend would only reduce GHG emissions by 1%).[81]

The Ontario Government is also calling on the Federal Government to create a national carbon trading system.[82] No specific actions have been announced regarding the Ontario Government's own fleet, other than the Government is installing two E85 fuelling stations for their E85 vehicles.

4.6.5 Municipal Governments

Toronto is recognized as a North American leader on climate change. In 1992, it established the Toronto Atmospheric Fund (TAF). The goal of this fund was to reduce the Municipalities' GHG emissions 20% by 2005; a goal Toronto is on track to meet. In addition to TAF, the City's Better Building Partnership funded retrofits of commercial and institutional buildings in order to make them more efficient, while creating considerable employment in the building trades. Energy savings paid back the initial investment.[83]

Since then, Canada's next two largest cities have followed Toronto's lead. The City of Montreal has committed itself to reducing the City's GHG emissions in line with Kyoto targets. In 2003, Vancouver set up the Cool Vancouver Task Force to reduce emissions from the City's operations 20% by 2010, and to reduce emissions from the wider Community 6% by 2010.[84]

Transportation is the largest source of GHG emissions in the City of Toronto and vehicles are the largest source of air contaminant emissions in Toronto.[85] The City's operations contribute 6% of the Greenhouse Gases emitted from Toronto every year. The remaining 94% of the GHG emissions originate from homes, apartments, commercial businesses, manufacturing plants, and vehicles.[86] While Canada's GHG emissions are 27% higher now than in 1990, Toronto's emissions are only 10% higher now than in 1990. The City has specific plans to make City Hall a showcase of environmental sustainability including energy efficiency retrofits, renewable energy, and a green roof. While the City has no specific plan to deal with their fleet of gasoline vehicles, it has planned to convert all of its diesel-powered vehicles to biodiesel by 2015.

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[81] David Suzuki Foundation – All over the Map: A comparison of provincial climate change plans – 2005 page 21, 22
[82] Go Green – Ontario's Action Plan on Climate Change – August 2007 page 30
[83] David Suzuki Foundation – All over the Map: A comparison of provincial climate change plans – 2005 page 4
[84] David Suzuki Foundation – All over the Map: A comparison of provincial climate change plans – 2005, page 4
[85] City of Toronto – Change is in the Air – Toronto's commitment to an environmentally sustainable future – March 2007, pages 3 and 4
[86] City of Toronto – Change is in the Air – Toronto's commitment to an environmentally sustainable future – March 2007, page 17

Many municipalities have adopted environmental agendas but major municipalities in Ontario such as Toronto, Ottawa and Hamilton face significant fiscal issues. While there have been divisive debates in the City of Toronto on budget and fiscal issues including new taxes to residents, City Council voted unanimously (37-0) on July 16th, 2007 in favour of a plan that aims to cut Greenhouse Gases in the city by 6% by 2012, 30% by 2020 and by a full 80% by 2050. The Plan goes beyond the Kyoto Protocol targets.

4.6.6 Private Sector

Ever increasingly, companies are being held accountable for their environmental footprint. Shareholders are asking for reporting on environmental performance and on how corporations are handling climate change. Corporations are adjusting slowly to the increased scrutiny on environmental issues. Just 88, of Canada's top 200 companies by market capitalization, provided details to a worldwide survey of how their corporations are tackling climate change.[87] Investor pressure for this information is growing. Thirty Canadian institutional investors, including all of the major Canadian banks, are now signatories to the Carbon Disclosure Project (CDP). The CDP asks companies 10 questions on subjects ranging from emission reduction strategies to the impact of changing weather patterns on operations, in an attempt to highlight climate change-related risks and opportunities.

The Canadian Council of Chief Executives has recognized that achieving sustainable development and dealing with climate change issues is the most fundamental challenge facing the world today.[88] Canada's business leaders are committed to addressing the challenges of sustainable development and in particular, climate change, and have issued a policy declaration. The Council also believes that Canada has the potential to be an environmental superpower. The Council has highlighted five points:

- Canada needs a national plan of action, one that sees governments, industry and consumers working together effectively toward shared goals;
- The core of this plan must focus on investment in the new technologies that can strengthen Canada's economic future while improving the environment at home and abroad;
- Targets are an important spur to action, but they must be framed in a way that both encourages and enables Canadian enterprises to increase investment in new technologies;

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[87] Globe and Mail – October 10, 2007 – Corporate response to carbon survey falls short
[88] Canadian Council of Chief Executives – Clean Growth, Building a Canadian Environmental Super Power – October 1, 2007

- Governments must consider carefully the most effective ways to harness market forces through price signals to businesses and consumers alike; and
- Canada's own environmental performance must enable us to champion credibly an inclusive global approach that can win the participation of all major emitters of Greenhouse Gases and pollutants.[89]

4.6.7 Consumers

A recent study conducted in the United States and United Kingdom confirms that consumers are very interested in the efforts companies are expending to address climate change. The survey indicated consumers believe that governments should play the lead role in helping reduce climate change and that, following closely, business should be significantly involved. Consumers felt the involvement of individuals and non-government organizations were less important to reducing climate change than government and business. Furthermore, the study revealed that people currently rate non-government organizations as first in playing a major role in dealing with climate change.[90] The study also concluded that there is a substantial opportunity for brands to engage consumers in tackling climate change, for the good of the brand, the consumer and the planet. More people have actively selected a brand for its good environmental practices than have avoided a brand for its bad ones.

Embracing environmental leadership can lead to increased brand awareness and potentially lead to market share advances. The best recognized brands for their environmental leadership in the transportation segment are Toyota (the market leader for hybrid vehicles) and BP (a leading fuels provider – beyond petroleum).[91] With the public's heightened awareness, governments and business will have to take a more active role in dealing with climate change and the perception of consumers. Alternative transportation fuels programs including propane can be highly visible and can lead to improved brand awareness and favourable public perception from good environmental practices.

4.6.8 Responding to the Challenge

The environmental concerns and issues swirling in the Canadian public and private sector are complex and inter-related. Organizations in all sectors, in an

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[89] Canadian Council of Chief Executives – Clean Growth, Building a Canadian Environmental Super Power – October 1, 2007 - page 11
[90] Consumers, Brands and Climate Change – The Climate Group, Sky, Lippincott – July 2007, executive summary
[91] Consumers, Brands and Climate Change – The Climate Group, Sky, Lippincott – July 2007, page 6

effort to improve their environmental footprints, are reviewing the status quo, developing action plans, and implementing programs. Current technology, potential technology, multiple opportunities for improvement, multiple stakeholders, and many other factors, help to shape an organization's environmental strategy.

Propane as a transportation fuel is ideally positioned to assist governments and the private sector with their efforts to address environmental issues. Propane as a transportation fuel is ready for implementation immediately; offers air quality improvements; GHG emissions reductions; lower fleet operating costs; the security of an abundant Canadian supply; the availability of refuelling infrastructure; and, the opportunity for export of Canadian technology into the North American marketplace.

4.7 Government Policies

The research team concluded that:

"Propane as a transportation fuel, is most widely in use in countries where governments at all levels have introduced stable long-term policies and programs aimed at introducing and establishing propane as a mainstream competitor against conventional transportation fuels."

4.7.1 Governmental policies can positively or negatively affect the adoption of transportation fuel alternatives

The fundamental factors affecting fuel choice for public and private fleet operators are as follows:

- **Life-cycle operating costs;**
- **Environmental impacts;**
- **Security of fuel supply;**
- **Fuel price stability; and**
- **Refuelling infrastructure.**

Government policies can affect these fundamentals, and can, therefore, positively or negatively affect the speed and magnitude of adoption of alternatives to gasoline and diesel fuel. Governments will develop positions and approaches based upon public goals such as national energy security, GHG performance, and air quality performance.

There are many examples around the world of both the positive and the negative effects of governmental influence in the marketplace via programs that adjust the net life-cycle cost performance for the vehicle owner. These programs have been proven to have significant influence in countries such as Australia[92], New Zealand[93], Germany[94], and India[95].

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[92] "Prime Minister Primes Australian Market for Autogas", Autogas Update, Global Autogas Industry Network, Number 22, Fall 2006

[93] Open Letter to the Secretary of the Treasury, New Zealand Federal Government, from Origin Energy Ltd. Regarding the Fuel Taxation Inquiry, 22 March 2002

[94] Richard Hareiner, President of the German LP Gas Association.

[95] "Car manufacturers go green in India", Autogas Update, Global Autogas Industry Network, Number 22, Fall 2006

4.7.1.1 *Case Study: Australia*

The Australian Government introduced a program to encourage the public to convert vehicles to automotive propane. The *LPG Vehicle Scheme* introduced on August 14th, 2006 enjoyed an exceptional response and after one year over 70,000 vehicles were converted. The Program runs for eight years and is uncapped so all eligible persons will be able to receive the grant.[96] It is expected that incremental conversions in Australia will exceed 240,000 vehicles by 2010.

The Program was dramatically successful; combining Program longevity with governmental incentives that dramatically improved the payback for the conversion technology investment for each vehicle. The Program pays a rebate of A$2,000 toward the cost of converting any vehicle.[97] With an average cost of A$2,500 per vehicle, the net cost to the consumer is A$500. Australia also has fuel taxes that favour propane by 60% over gasoline. Consequently, the conversion costs for a vehicle traveling only 15,000 kms per year can be recouped in less than 20 weeks.

The Program has also created additional benefits for Australia as under hood technology is exported to Southeast Asia, the United States and other countries around the world. Australia has a well-developed infrastructure of fuelling stations and the dispenser and nozzle technology is amongst the best in the world (with exports to propane-consuming nations including Canada). A robust propane technology industry has been created in Australia, and propane research and development activities have spread to other sectors including agriculture.

As an additional observation, net conversion is more expensive in Canada and takes much longer to pay back due to the fact that Australian automotive propane enjoys twice the pump price advantage over gasoline than is present in the Canadian scenario. The very high number of kilometres required to recoup the conversion costs in Canada make switching from gasoline to propane uneconomical unless the vehicles are high fuel consumption vehicles like police fleets, taxis and package delivery fleets. Table 7 shows a comparison of the net conversion costs, fuel savings and adoption rates in Ontario and Australia.

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[96] Media release – Australian Government, www.ausindustry.gov.au - August 16, 2007
[97] "Prime Minister Primes Australian Market For Autogas", Autogas Update, Global Autogas Industry Network, Number 22, Fall 2006

Table 7

Ontario and Australia
Net conversion costs, Fuel savings and Adoption rates

	Australia	Ontario
Average conversion cost	A$ 2,500	C$ 6,384
Rebate available	(A$ 2,000)	(C$ 750)
Net cost of conversion	A$ 500	C$ 5,634
Fuel saving per litre vs. gasoline	60%	40%
Kilometres required to break even	< 10,000	> 60,000
Propane % of market 2004	5%	<2.0%
Propane % of market 2007	9%	<2.0%

4.7.1.2 Case Study: India LPG

India's experience illustrates the potential of government to influence the availability of alternative fuels technology. India reduced its fuel excise tax from 24% to 8% for propane and natural gas used in small vehicles. As a result, India's largest automobile manufacturer, Maruti Udyog Ltd. has announced plans to expand production of propane-powered vehicles. Toyota and GM have also announced plans to introduce similar models.[98]

4.7.1.3 Case Study: Germany

Germany's experience demonstrates that the market will adjust to its impression of the stability of the government programs that are in place. Legislation was introduced in the German Bundestag in July 2006, aimed at extending (from a termination date of 2009) the favourable excise treatment of propane to 2018. The reactions in the industry were immediate. Conversions went up within 30 days and the 1,700 filling stations across the Country were expected to grow to over 6,000 by 2010.[99]

4.7.1.4 Case Study: New Zealand

New Zealand's experience proves that any government-sponsored adjustment to the marketplace dynamics should be adjusted with care. New Zealand introduced a series of policies commencing in the 1980's aimed at encouraging

[98] "Car manufacturers go green in India", Autogas Update, Global Autogas Industry Network, Number 22, Fall 2006
[99] Richard Hareiner, President of the German LP Gas Association.

the use of propane and CNG as transportation fuels. Propane use in transportation flourished and a healthy infrastructure grew. In the early 1990's the Government of New Zealand reversed itself, imposing excise taxes on propane and CNG. The results are outlined in an open Letter to the Secretary of the Treasury, New Zealand Federal Government, from Origin Energy Ltd. regarding the Fuel Taxation Inquiry, dated March 22, 2002, as follows:

> *"We would like to draw the Inquiry's attention to the impact that an absolute tax excise had on the consumption of LPG and CNG in New Zealand when introduced in the 1990's.*
>
> *New Zealand in the late 1980's had approximately 100,000 CNG and 50,000 LPG vehicles. An excise tax (currently 10.4cpl) was introduced in the early 1990's. The impact has been a severe reduction in the consumption of CNG and LPG; such that the fleet of CNG vehicles is today below 1,000 and LPG powered vehicles number around 18,000 to 19,000 vehicles.*
>
> *In understanding this dramatic reduction in consumption it is worth noting the own and the cross-price elasticity of LPG and CNG relative to alternatives. The experience in New Zealand strongly suggests the own-price elasticity of LPG and CNG is both positive and high. The 10.4cpl excise on LPG and CNG altered the relative prices of traditional motor spirit to alternative fuels. The support of these fuels collapsed, though the bulk of the distribution infrastructure remains in place and operable today."*[100]

New Zealand is currently embarking on another 1980's style policy direction aimed at encouraging propane use in transportation. Unfortunately, most senior managers in industry today were around during the 1980's and 1990's and the Government is being greeted with "here we go again" scepticism.

4.7.1.5 Miscellaneous Incentives

Many cities are experimenting with the restriction of certain gasoline and diesel powered vehicles in densely populated areas. Cities in Japan, Korea, Italy, Germany, and India have, or are still experimenting with, restrictions on certain vehicles and are simultaneously increasing incentives for alternative fuels used in the same areas. These initiatives, combined with strict enforcement of idle time limits are all aimed at improving air quality in the cities. Some jurisdictions

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[100] Open Letter to the Secretary of the Treasury, New Zealand Federal Government, from Origin Energy Ltd. Regarding the Fuel Taxation Inquiry, 22 March 2002

allow alternative fuel vehicles to use high-occupancy vehicle lanes on highways.

4.7.2 The Canadian Scenario

Governments in Canada currently face a number of realities that may influence their approach to alternative fuels. A few of these considerations include:

- Greenhouse Gas emissions reductions are a subject of much concern for Canadians, and can be significantly curtailed by the creative adoption of various energy alternatives to gasoline and diesel.
- Municipal, Provincial and Federal budgetary pressures that exist could be reduced through the application of energy alternatives that yield significant operating cost reductions.
- North American gasoline and diesel refinery capacity is nearing 100% utilization and will take a number of years to rectify.
    - Refinery Capacity issues will create supply disruptions, supply insecurity, and severe price fluctuations which will impact the Canadian motoring public as well as fleet users.
- Canada's propane resources are significantly under-utilized at present, and can be deployed to mitigate some of the pressures created by the refinery utilization situation.
    - Approximately 70% (8.6 Billion Litres) of Canada's annual production of propane is exported due to lack of domestic demand.
    - Utilization of excess propane supply could reduce gasoline demand by up to 20%, easing the refinery capacity issues, and contributing to petroleum price stability for all Canadians.
- The Canadian public are looking to the Government to lead by example, with initiatives to address budgetary concerns (fiscal responsibility) and to improve environmental performance.
- Canadian companies have developed innovative technologies for under hood propane applications and for the dispensing of propane to vehicles. These technologies and innovations can be expanded to world markets.

The experience worldwide demonstrates that government policy and programs have the ability to dramatically influence the adoption of alternative fuels. Similarly, Government's have the ability to significantly adjust the viability of one alternative over another. As world experience has shown, significant adjustments to one fuel without corresponding adjustments to others can quickly re-adjust the marketplace equilibrium.

All levels of Government within Canada have another tool that can quickly be utilized to support and encourage the adoption of alternative fuels. The implementation of alternative fuel technologies within the government controlled fleets positively signals the marketplace and effectively demonstrates the viabilities of the various choices, reducing perceived risk to other adopters, and encouraging adoption by the private sector.

5. CONCLUSIONS

The research team concluded that:

"The evidence is clear, irrefutable, and comes from many independent sources: Propane is the best choice of transportation fuel for light-duty fleet operators in Canada, who want to reduce operating costs, while reducing harmful emissions."

Gasoline and diesel are far and away the two most widely used transportation fuels for commercial fleets of light-duty vehicles like police cars, taxis, delivery units and school buses. The problem is that these fuels are damaging to the environment and to people's health and they are becoming increasingly expensive. The recent rise in concern for the environment has prompted politicians and fleet operators to consider alternatives to the two incumbent fuels of choice.

The key operating issues for fleet operators are performance, availability, and costs. Unless these criteria are met, fleet operators will vigorously fight changes and/or legislation favouring alternative fuels.

The researchers eliminated fuels such as hydrogen, methanol and electricity as being too nascent. These fuels will not be available at a reasonable cost or in sufficient quantities for at least for the next two decades. Biodiesel and E85 are expensive and are also not available in sufficient quantities to meet demand today.

Propane emerged as the best alternative to gasoline and diesel based on cost, performance, availability, and impact on the environment. Specifically, propane proved better than gasoline and diesel on the following dimensions:

- ***"Propane as a transportation fuel is:***
    - ***25% less expensive than conventional gasoline;***
    - ***28% less expensive than E10 ethanol-blended gasoline;***
    - ***50% less expensive than E85 ethanol-blended gasoline;***
    - ***11% less expensive than diesel; and***
    - ***9% less expensive than natural gas***

  when evaluated on a full life-cycle basis, with consideration for all costs of conversion."

- ***"Propane is more environmentally friendly than gasoline or diesel, emitting up to 26% less Greenhouse Gases than conventional gasoline and significantly less emissions of criteria air contaminates and air toxics that impact air quality and human health."***

- ***"There is an abundance of propane in Canada available to meet the transportation sector needs. Propane from domestic sources could replace up to 20% of domestic gasoline demand."***

- ***"Propane pricing has been, and is likely to be, more stable than gasoline, diesel, and ethanol-blends well into the future."***

- ***"Propane is the most readily accessible and available alternative fuel in Canada, and additional infrastructure is easily installed as fleet-specific needs arise."***

- ***"Propane as a transportation fuel is ideally positioned to assist governments and the private sector with their efforts to address environmental issues."***

- ***"Propane as a transportation fuel, is most widely in use in countries where governments at all levels have introduced stable long-term policies and programs aimed at introducing and establishing propane as a mainstream competitor against conventional transportation fuels."***

The evidence is clear, irrefutable, and comes from many independent sources:

> ***"Propane is the best choice of transportation fuel for light-duty fleet operators in Canada, who want to reduce operating costs, while reducing harmful emissions."***

6. GLOSSARY OF TERMS

acetaldehyde	Toxic compound in engine exhaust gases: produced from combustion of all fossil fuels
AFA	Alternative Fuels Act of 1995 (Canada)
AFV	Alternative fuel vehicle
AFVI	Alternative Fuels Vehicle Institute
ANL	Argonne National Laboratory – U.S. DOE's oldest and largest science and engineering research laboratory
Air Toxics	Toxic air pollutants are those pollutants that are known to cause cancer or other serious health effects – include acetaldehyde, benzene, 1,3-butadiene, toluene
Auto ignition temperature	Temperature at which a fuel will spontaneously ignite when mixed with air
ATF	Alternative transportation fuel
B20	Blend of 20% by volume of vegetable oil or animal fat ester and 80% by volume of diesel fuel; see biodiesel
BC	Black carbon - a form of carbon produced by incomplete combustion of fossil fuel or biomass
BCF	Billions of cubic feet – natural gas volume measurement
bifuel	Vehicle with two fuel systems, of which only one can be used at a time
biodiesel	Fuel made from vegetable oils or animal fats and used in diesel engines, typically in a blend (e.g. B20) with conventional diesel fuel
biofuels	A liquid or gas transportation fuel derived from biomass
biomass	Biological material which can be used as fuel or for industrial production
BTU	British thermal unit, the energy needed to raise one pound of water one ° F

CAC	Criteria air contaminant
CDP	Carbon Disclosure Project
CAFE	Corporate Average Fuel Economy - sales-weighted average fuel economy, expressed in miles per gallon, of a manufacturer's fleet of current model year passenger cars or light trucks with a gross vehicle weight rating (GVWR) of 8,500 pounds or less
CARB	California Air Resources Board
carcinogenic	Carcinogen refers to any substance or agent directly involved in the promotion of cancer or in the facilitation of its propagation
CEC	California Energy Commission
clean diesel	Diesel fuel modified to achieve lower exhaust emissions: modifications typically include reducing the amounts of sulphur and aromatic hydrocarbons found in conventional diesel fuel
closed-loop	Emission control system that adjusts engine operation based on exhaust –gas composition
CNG	Compressed natural gas
CO	Carbon monoxide (exhaust emission caused by incomplete combustion)
CO_2	Carbon dioxide (a major Greenhouse Gas produced from combustion of carbon-containing fuels)
conventional fuel	Gasoline, diesel fuel, and other fuels derived from crude oil
criteria air contaminants	Emissions of various air pollutants that affect human health and contribute to air pollution – include TPM, PM_{10}, $PM_{2.5}$, SO_X, NO_X, VOC's, CO, and NH_3
criteria pollutant	Pollutant determined by the EPA to be hazardous to human health and subject to EPA regulations
CSA	Canadian Standards Association – standards for safety and performance

cylinder	High-pressure storage container for gases
dedicated	Vehicle with only one fuel system
denaturant	Toxic, foul-tasting, or foul-smelling substance added to ethanol to discourage human consumption
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
E10	Blend of 10% by volume of ethanol and 90% by volume of gasoline
E85	Blend of 85% by volume of ethanol and 15% by volume of gasoline
electrolysis	Electrolysis is a method of separating chemically bonded elements and compounds by passing an electric current through them. Electrolysis of water yields hydrogen and oxygen.
EPA	U.S. Environmental Protection Agency
EPACT	Energy Policy Act of 1992 (US)
ERC	Emission reduction credit
ETBE	Ethyl tert-butyl ether - commonly used as an oxygenate gasoline additive
EV	Electric Vehicle
FFV	Flexible Fuel Vehicle – vehicle able to use alcohol fuels or gasoline, or any blend of alcohol and gasoline usually up to 85% alcohol by volume
formaldehyde	Toxic compound in exhaust gases: produced from combustion of all fossil fuels
FTP	Federal Test Procedure – driving cycle used by EPA to certify light-duty vehicles for emissions
fuel cell	Energy-conversion device that produces electricity from hydrogen or fuels that contain hydrogen
full fuel cycle	Tracking all inputs and outputs of fuel production and use, from resource through combustion

gasohol	Blend of 10% by volume of ethanol in gasoline (E10)
GJ	Gigajoule – SI unit of energy
GHG	Greenhouse Gases
global warming	Theory that the average temperature of the earth's atmosphere is increasing
Greenhouse Gas	Gases in atmosphere, such as carbon dioxide, that trap solar radiation and increase the average temperature of the earth's atmosphere
GREET Model	Greenhouse Gases, Regulated Emissions, and Energy use in Transportation – ANL has developed a full life-cycle model allowing researchers to evaluate various vehicle and fuel combinations on a full fuel-cycle/vehicle-cycle basis.
GVW	Gross vehicle weight
GVWR	Gross vehicle weight rating
HC	Hydrocarbon emissions – vehicles emit HC from tailpipes due to incomplete combustion and from fuel systems due to evaporation
HDE	Heavy duty engine
HDV	Heavy duty vehicle
HEV	Hybrid electric vehicle
Kyoto Protocol	The Kyoto Protocol is an agreement made under the United Nations Framework Convention on Climate Change (UNFCCC). Countries that ratify this protocol commit to reduce their GHG emissions.
LEV	Low emission vehicle (California emission standard)
LDV	Light-duty vehicle – GVW less than 8500 lbs, typically passenger cars and light trucks
LNG	Liquefied natural gas (natural gas turned to liquid by cooling to minus 260°F
LPG	Liquefied petroleum gas (synonymous with propane)

M85	Blend of 85% by volume of methanol and 15% by volume of gasoline
metal hydride	Alloy that can store hydrogen within the alloy's internal structure, at relatively low pressure
mpg	Miles per gallon
mph	Miles per hour
MTBE	Methyl tertiary butyl ether – oxygenated additive made from methanol and used in reformulated and oxygenated gasoline
NAAQS	National Ambient Air Quality Standards (set by EPA)
NMHC	Non-methane hydrocarbons (hydrocarbon emissions minus the methane component; provides a better measure of ozone-forming potential because methane does not participate significantly in reactions that produce ozone)
non-attainment	Failure of a geographic region to comply with NAAQS
NO_x	Oxides of nitrogen (exhaust emission caused by high temperature combustion)
NRCan	Natural Resources Canada
O_2	Oxygen
OBDII	On-Board Diagnostics – second generation, a vehicle's self-diagnostic and reporting capability
octane rating	The resistance of a fuel to auto ignition, usually expressed as the average of the research and motor tests, or (R+M)/2
OEM	Original Equipment Manufacturer – refers to vehicles and parts produced by a vehicle manufacturer, as opposed to parts produced by another company (aftermarket supplier) for add-on to the vehicle
OMA	Ontario Medical Association

OPEC	The Organization of the Petroleum Exporting Countries is an international cartel made up of Iraq, Indonesia, Iran, Kuwait, Libya, Angola, Algeria, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates and Venezuela
open-loop	Emission control system that cannot adjust engine operation based on exhaust-gas composition
oxygenated gasoline	Gasoline to which oxygen-containing components, such as alcohols or ethers, have been added to reduce carbon monoxide and other emissions
ozone	An atmospheric gas that, at ground level is considered an air pollutant and is created from reactions between vehicle emissions in the presence of sunlight
PM	Particulate matter (exhaust emission; diesel engines produce large quantities of PM)
$PM_{2.5}$	Particulate matter with mean diameter less than 2.5 microns
PM_{10}	Particulate matter with mean diameter less than 10 microns
psi	Pounds per square inch (unit of pressure)
PTW	Pump to wheels; used in calculating life-cycle emissions of vehicles and fuels
RFG	Reformulated Gasoline; gasoline that has been specially formulated to reduce exhaust emissions
regenerative braking	In an electric or hybrid electric vehicle, energy otherwise absorbed (thrown away as heat) by the brakes that is instead used to generate electricity that helps recharge the batteries
smog	Visible haze caused by air pollution
SO_x	Sulphur Oxides
TCF	Trillions of cubic feet; natural gas volume measurement

THC	Total hydrocarbon emissions
TPM	Total Particulate Matter
toxics	Any air pollutant that may cause cancer or other serious health problems; EPA-defined examples of toxics from conventional fuels include benzene, formaldehyde, acetaldehyde, and 1,3-butadiene
UL	Underwriter Laboratories
ULEV	Ultra low-emissions vehicle (California emission standard)
unregulated emissions	Emissions from vehicles that are not currently regulated by authorities – includes air toxics: 1,3-butadiene, acetaldehyde, benzene and formaldehyde
VOC	Volatile organic compound (exhaust and evaporative emissions; synonymous with HC)
WTP	Well to pump; used in calculating life-cycle emissions of vehicles and fuels
WTW	Well to wheels; used in calculating life-cycle emissions of vehicles and fuels
ZEV	zero-emissions vehicle (California emission standard; synonymous with electric vehicle)

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