THE FEASIBILITY OF ADOPTING NATURAL GAS AS A VEHICLE FUEL FOR MANITOBA SCHOOL BUS FLEETS

BY

DAVID W. MOLINSKI

A Practicum Submitted In Partial
Fulfillment of the Requirements for the Degree
Master of Natural Resources Management

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A Thesis/Practicum submitted to the Faculty of Graduate Studies of the University of Manitoba in partial fulfillment of the requirements for the degree of

MASTER OF NATURAL RESOURCES MANAGEMENT

ABSTRACT

Interest in alternative transportation fuels has grown over the last few years. However, many questions arise regarding fuel availability, vehicle costs, refueling requirements, economic viability and environmental impacts. With any new technology, potential consumers must have impartial information available to compare between alternative fuels. One alternative fuel now being seriously examined is natural gas. This study focused on the feasibility of adopting natural gas as a vehicle fuel for Manitoba school bus fleets.

The objective of this practicum was to provide decision makers with impartial information upon which to base their decisions regarding the potential conversion of school buses to operate on natural gas. There were three sub-objectives: 1) analysis of the economic potential of adopting natural gas as a vehicle fuel; 2) analysis of potential reductions in tailpipe emissions if school bus fleets are converted to natural gas operation; and, 3) analysis of the technological viability of natural gas as a vehicle fuel. Included with this practicum is a computer disk copy of the spreadsheet model used to analyze the economic and environmental impacts of converting school buses to use natural gas.

The economic analysis indicated that four of the eight school divisions assessed produced positive net present values. The conversion of school buses to operate using natural gas in these four school divisions would result in reductions of tailpipe emissions. Analysis of the technical feasibility indicated that conversion of school buses to operate on natural gas is technically feasible from both operational and refueling aspects.

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CHAPTER I

BACKGROUND

1.1. Introduction

Interest in alternative transportation fuels has grown over the last few years. The support for alternative fuels is demonstrated by the three major North American automobile manufacturers offering alternatively fueled vehicles in their fleets. As Lyons and McCoy (1993) note, now that alternative fuels are being seriously examined by both consumers and the transportation industry, many questions arise regarding fuel availability, vehicle costs, refueling requirements, economic viability and environmental performance. With any new technology, potential consumers must have impartial information available that fully addresses these issues to compare between alternative fuels. One fuel now being seriously examined by fleet operators is natural gas; making the availability of complete and impartial information important.

"Natural gas is an excellent fuel for transportation as well as one of Canada's most abundant fuel resources" (Heath, 1991). In the past, the marketing of natural gas as a transportation fuel in Canada was dependent on the price difference between natural gas and gasoline. Natural gas fuel marketers have focused on the price advantage and the relative price stability of this indigenous resource to expand the use of natural gas as a vehicle fuel. Crude oil based fuels have been subject to wide price fluctuations in response to supply and demand fundamentals of the global market; most recently during the Persian Gulf Crisis. With the concern for environmental quality firmly established in the psyche of most Canadians, the environmental benefits of using natural gas as a vehicle fuel has become another important reason to examine this fuel option.

The Canadian government has made an international commitment to stabilize greenhouse gas emissions at 1990 levels by the year 2000 (Environment Canada, 1993). Substituting natural gas for gasoline would reduce vehicle emissions of carbon monoxide, carbon dioxide, reactive hydrocarbons, and nitrogen oxides. Expanding the use of natural gas as a vehicle fuel would contribute to achieving this goal.

The federal government has initiated several programs to encourage the use of natural gas as a transportation fuel. Among them are: the Natural Gas Vehicle Program; the Residential Refueling Appliance Program; the Natural Gas Fueling Station Program; and the Commercial Natural Gas Compression Program (Heath, 1991). Although these programs represent the commitment the federal government has made to the adoption of natural gas as a vehicle fuel, these programs will expire in April 1997 (Turner, personal communication).

The Manitoba government has indicated it supports in principle the policy to stabilize greenhouse gas emissions at 1990 level by the year 2000 (McVicar, personal communication). As it recognizes that using natural gas as a vehicle fuel contributes to achieving this goal, the province does not apply a road tax to natural gas when used as a vehicle fuel (McVicar, personal communication).

Centra Gas Manitoba Inc. (Centra Gas) is the natural gas distributor in Manitoba, serving approximately 100 communities. This company is a subsidiary of Centra Gas Inc. of Vancouver, British Columbia, which is owned by Westcoast Energy Inc. As the natural gas distributor in Manitoba, Centra Gas recognizes it will increasingly be judged on its ability to contribute to cleaner air, improving end-use energy efficiency, supporting the principles of sustainable development, and reducing emissions that contribute to global warming. Several years ago Centra Gas identified natural gas vehicles as a business opportunity to be developed that would also address the above issues. In 1995, Centra Gas Inc. formed Centra Energy Services (CES) as a non-regulated division with a mandate to pursue new markets for the use of natural gas (Weekes, personal communication).

CES has launched an initiative to market the use of natural gas as a vehicle fuel in Manitoba. School bus fleets are one of the target markets. Other targeted markets include other fleet applications such as taxi cabs and short haul delivery vehicles. CES is pursuing a two pronged initiative with marketing plans developed in two areas. First, it is providing optimal, cost effective technology for converting customers' vehicles to operate using natural gas. Second is the provision of natural gas fueling facilities and infrastructure. The marketing plans addresses economic and environmental impacts, energy security issues, provincial/public benefits and implementation plans (Turner, personal communication).

Currently, there are 104 school buses in six different Manitoba school divisions using natural gas as a vehicle fuel (Hanson, personal communication). These school buses are equipped with dual-fuel natural gas conversions that allow the buses to operate on either natural gas or gasoline. The Seven Oaks School Division has been the most aggressive Manitoba school division to convert school buses to use natural gas. This school division has converted over half of its 42 school buses to operate on natural gas. Although there have been technical difficulties concerning certain vehicle conversions and the refueling facilities that must be overcome, the Transportation Supervisor has expressed confidence in the dual fuel conversions (Salter, personal communication). Most importantly however, the fuel cost savings and environmental benefits from using natural gas as a vehicle fuel have been extremely positive for this division (Salter, personal communication). Other school divisions in Manitoba are following the progress of the natural gas school bus conversions. Therefore, a systematic examination of the potential benefits for other school divisions is both timely and warranted.

1.2 Problem Statement

Natural gas can be used as an alternative transportation fuel. Natural gas is less expensive and produces fewer tailpipe emissions than gasoline. While the use of natural gas as a vehicle fuel in school bus fleet applications shows promise, school divisions require a technical, economic, and environmental assessment of converting school buses to operate on natural gas so that they can make appropriate decisions.

1.3 Research Objectives

The objective of this project is to provide decision makers with impartial information upon which to base their decisions regarding the potential conversion of school buses to operate on natural gas.

The project has several sub-objectives which determine the scope and types of analyses required. They include:

1. economic analysis of adopting natural gas as a vehicle fuel in provincial school bus fleets;
2. analysis of potential reductions in tailpipe emissions if school bus fleets are converted to natural gas operation;
3. analysis of the technological viability of natural gas as a vehicle fuel, including discussions on
    a) vehicle performance
    b) maintenance and servicing
    c) safety; and,
4. recommendations resulting from the analysis.

1.4 Limitations

Natural gas is not currently available in all areas of Manitoba. Only those school divisions that are currently supplied by natural gas will be considered for conversion. Table 1 indicates the school divisions with access to natural gas:

Table 1: Manitoba School Divisions With Access To Natural Gas

Agassiz School Division	Morris-McDonald School Division
Antler River School Division	Norwood School Division
Assiniboine South School Division	Pelly Trail School Division
Beautiful Plains School Division	Portage la Prairie School Division
Birdtail River School Division	Red River School Division
Boundary School Division	Rhineland School Division
Brandon School Division	River East School Division
Dauphin - Ochre S.A.	Seine River School Division
Division Scolaire Franco-Manitobaine	Seven Oaks School Division
Evergreen School Division	Souris Valley School Division
Fort Garry School Division	St. Boniface School Division
Fort La Bosse School Division	St. James Assiniboia School Division
Frontier School Division	St. Vital School Division
Garden Valley School Division	Transcona - Springfield School Division
Hanover School Division	Turtle Mountain School Division
Interlake School Division	Western School Division
Lord Selkirk School Division	White Horse Plains School Division
Midland School Division	Winnipeg School Division

The potential total number of school bus conversions is limited by the availability of natural gas as indicated above. Discussions with staff from the Manitoba Department of Education and the Manitoba Association of School Trustees indicated that there is no comprehensive listing is available of the number of school buses and fuel types within school divisions. Given that data for this research was not obtained from all school divisions with access to natural gas, it is not possible to accurately estimate the total potential conversion fleet for school divisions in Manitoba.

As of February 1997, there were approximately 1,600 school buses in use in Manitoba (Hanson, personal communication). As will be discussed later in this report, vehicles using diesel fuel and propane cannot be converted to use natural gas as a vehicle fuel. Of the 1,600 school buses in use, approximately 490 buses use diesel fuel, 74 buses use propane, and 104 are already converted to use natural gas. Therefore the potential maximum number of school buses that may be converted to use natural gas as a vehicle fuel is 932 units.

1.5 Research Methodology

The following research methodology was used to analyze the economic and environmental benefits of converting school buses to operate on natural gas so that school divisions can make appropriate decisions.

1.5.1 Review of Related Research

Information for this study was drawn from relevant literature, through discussion with individuals in the natural gas industry, Manitoba school divisions, the Department of Education and the Manitoba Association of School Trustees. A review of related research and literature was necessary to provide the author with the basic knowledge needed to initiate a comprehensive and complete study. In order to develop background knowledge, economic evaluations on the use of natural gas as a vehicle fuel for school buses in other jurisdictions were also reviewed to provide background on research methodologies. The literature review was conducted with the aid of computer searches for journal articles, published literature, and the Internet sites.

1.5.2 Data Gathering

Manitoba school division Transportation Supervisors were surveyed to collect fleet level data on fuel consumption, fuel costs, daily routes and the age of each bus. Additional survey questions related to bus replacement policies, fuel preference and the perception of natural gas as a vehicle fuel. Where insufficient data were provided by the survey, the Department of Education and the Manitoba Association of School Trustees were contacted to ascertain the availability of data. CES provided information on current vehicle conversion and refueling facility costs.

1.5.3 Economic Analysis

The analysis of the economic feasibility of adopting natural gas as a vehicle fuel was based on an economic model developed on the principles of financial evaluation. This model calculated the net present value and net annualized savings resulting from school divisions converting their school bus fleet to operate on natural gas. The net present value demonstrate the economics of the project without the use of financing. The net annualized savings demonstrate the economics of the project if it were financed over the period of analysis.

The financial evaluation includes only those benefits and costs incurred by school divisions. The rationale for choosing this method of analysis was that school divisions base their decisions solely on the impact to their budgets. They, for the most part, appear to ignore the potential impact on Centra Gas, CES or the wider impacts to the provincial budget.

1.5.4 Emissions Analysis

Analysis of the impact on tailpipe emissions was prepared concurrently with the economic analysis. The tailpipe emission compounds addressed by this research included total hydrocarbons (THC), non-methane hydrocarbons (NMHC), carbon monoxide (CO), nitrogen oxides (NOx), and carbon dioxide (CO_2). The data source for the change in tailpipe emissions was from Lyons and McCoy (1993). The change in tailpipe emissions was calculated by multiplying the total distance traveled using natural gas as a vehicle fuel by the per kilometre difference in natural gas versus gasoline tailpipe emissions.

1.6 Organization of Practicum

Chapter 2 of the research discusses the use of natural gas as vehicle fuel. This includes a discussion of the physical properties of natural gas, supply and demand considerations, the availability of natural gas in Manitoba, the use of natural gas as a vehicle fuel and relevant safety issues. Chapter 3 examines the methodology used in analyzing the economic and emissions impacts of converting school buses to operate using natural gas. Chapter 4 describes the economic and emissions parameters used in the analysis of the school bus fleets. The results of the analysis are then presented followed by a discussion of the results. Chapter 5 provides a summary of the research and the conclusions and recommendations that were drawn from the analysis.

CHAPTER 2

NATURAL GAS AS A VEHICLE FUEL

2.1 Introduction

The use of natural gas is expanding from such uses as residential space and water heating and commercial and industrial space and process heating, to being used as a vehicle fuel. When considering whether to use natural gas as a vehicle fuel, two basic questions are asked. Does natural gas exhibit similar characteristics to gasoline such as ease of fueling, smooth ignition, good drivability, safe operation and good fuel economy; and, what are the costs to convert and maintain a vehicle and construct fueling facilities?

This section examines the use of natural gas as a vehicle fuel, with specific reference to school buses. It begins by examining the physical properties of natural gas and is followed by a discussion of supply and demand considerations. This is followed by an examination of the requirements for vehicle conversion and fueling facilities. Tailpipe emissions from natural gas vehicles are then be compared to gasoline fueled vehicles. The safety of natural gas as a vehicle fuel is then reviewed. Finally, the decision to convert existing and new buses is discussed.

2.2 The Physical Properties of Natural Gas

Natural gas is a colourless, odourless hydrocarbon which is much lighter than air. It is produced in its raw form from reservoirs beneath the earth's surface. Raw natural gas is composed primarily of methane (CH_4), which typically makes up 85 percent of the volume of natural gas. Other compounds found in raw natural gas include water vapour, ethane (C_2H_{10}), propane (C_3H_8), butane (C_4H_{10}), pentane (C_5H_{10}), hydrogen sulfide (H_2S), nitrogen (N_2), and carbon dioxide (CO_2) (Heath, 1991). Natural gas processing plants remove most of these substances, leaving processed gas made up of about 97 percent methane ready for transporting.

When compared to gasoline and diesel fuel, natural gas has about the same energy content by weight (Heath, 1991). As natural gas is gaseous, its energy content is significantly lower for an equivalent volume. Therefore, it requires pressurization for a vehicle to carry similar amounts of energy as gasoline. Table 2 summarizes the selected properties of natural gas and gasoline:

Table 2: Selected Properties of Natural Gas and Gasoline*

Property	Natural Gas	Gasoline
Flammability limits (vol. % in air)	5.3 - 15.0	1.0 - 7.6
Detonability limits (vol. % in air)	3.1 - 7.0	1.1 - 3.3
Autoignition temperature (degrees Celsius)	540	227 - 471
Energy Content - megajoules/kilogram (lower heating value)	10.2	9.1
Buoyant velocity in air (m/sec)	0.8 - 6	Nonbuoyant

* Singh (1985)

The flammability limits indicate the percentage of the fuel vapour that must be present in the atmosphere for the fuel to burn. The data contained in Table 4 indicates that a greater volume of natural gas than gasoline must be present in the atmosphere for the fuel to burn than for gasoline. The detonability limits of the fuels indicates the volume of fuel that must be present for the fuel to detonate or explode. Table 4 indicates that a greater volume of natural gas must be present in the atmosphere than gasoline for detonation to occur.

The autoignition temperature indicates the temperature required to cause the fuel to burn without the presence of an ignition source. Natural gas requires a higher temperature to ignite and burns at a higher temperature than gasoline. Also indicated in the table is the energy content for a given mass of fuel. As seen above, the energy content of natural gas is higher than gasoline for an equal mass. Finally, the buoyant velocity of natural gas indicates that it rises in the atmosphere at a rate of 0.8 to 6 metres per second, while gasoline is non-buoyant. This indicates that natural gas rises in the atmosphere while gasoline remains pooled on the ground.

2.3 Supply and Demand Considerations

It is estimated that Canada has 397 billion cubic metres per year of exportable gas surplus to the year 2010 (Sypher:Mueller, 1991). This is gas that is not required for current or future expected Canadian consumption and committed exports. This means that for each year till the year 2010, there will be an annual natural gas surplus beyond market demand. As well, a National Energy Board (NEB) supply and demand analysis found that Canada has natural gas reserves to production ratio of 22, which indicates that Canada has a reserve 22 times greater than its annual production level (Heath, 1991

Natural Resources Canada (1994) estimated that there was a natural gas reserve-production ratio of 18 years and a commercial resource base of 4.2 trillion cubic metres. These estimates are expected to be revised upwards because of improvements in natural gas recovery technology. Examining natural gas supply and trade from the year 1992 to the year 2020, Natural Resources Canada expects natural gas supply capability to exceed total domestic and export demand by about 10%, but concludes that any surge in gas demand above projected levels will narrow this figure.

Canadian natural gas exports account for about 10 - 12 percent of U.S. natural gas consumption (Natural Resources Canada, 1994). This figure is expected to remain stable at about 76 billion cubic metres per year over the long term. Natural Resources Canada (1994) however cautions that these projections are highly sensitive to the assumptions regarding the natural gas industry's reinvestment ratio, the prices for other energy sources, the level of economic growth for the entire economy and particular sectors.

Natural Resources Canada was contacted to determine if recent research indicates changes to the supply and demand outlook for natural gas. It was indicated that there is no concern about natural gas availability over the long term, as proven reserves of natural gas have remained stable over the past several years (Cassaubaum, personal communication). Furthermore, while Canadian demand for natural is expected to remain stable over the long run, an expected 25 percent increase in exports to the United States over the next decade will have little effect on the Canadian supply situation. Based on this outlook, Natural Resources Canada expects the price of natural gas at the wholesale level to increase at the rate of inflation. This means that consumers should experience stable real natural gas prices over the long term (Cassaubaum, personal communication).

2.4 The Supply and Distribution of Natural Gas in Manitoba

Manitoba's main source of natural gas is from gas wells in the province of Alberta with some additional natural gas being drawn from the provinces of Saskatchewan and British Columbia. Raw gas is gathered from wells and delivered to a common pipeline, and then transported to processing plants. Products such as propane, butane, pentane, nitrogen and carbon dioxide are removed and sold as commodities. Substances such as water vapour and hydrogen sulfide are removed to prevent corrosion of the distribution system (Heath, 1991).

Following processing, natural gas is gathered by the NOVA Pipeline and transported to the Alberta border. The TransCanada Pipeline (TCPL), which begins at the Alberta-Saskatchewan border, transports the gas to Saskatchewan, Manitoba, Ontario, eastern Quebec and into the United States. During the winter heating season, natural gas is delivered directly to Manitoba for immediate use. During the summer months, natural gas is transported to storage facilities contracted by Centra Gas in Michigan.

During the winter heating season, natural gas is withdrawn from storage and is used to replace natural gas destined for customers in eastern Canada (Manitoba Energy and Mines, 1996). This ensures that Manitoba customers has a safe and secure supply of natural gas and aids in reducing natural gas price volatility during the heating season. Figure 1 shows the natural gas distribution system operated in Manitoba by Centra Gas.

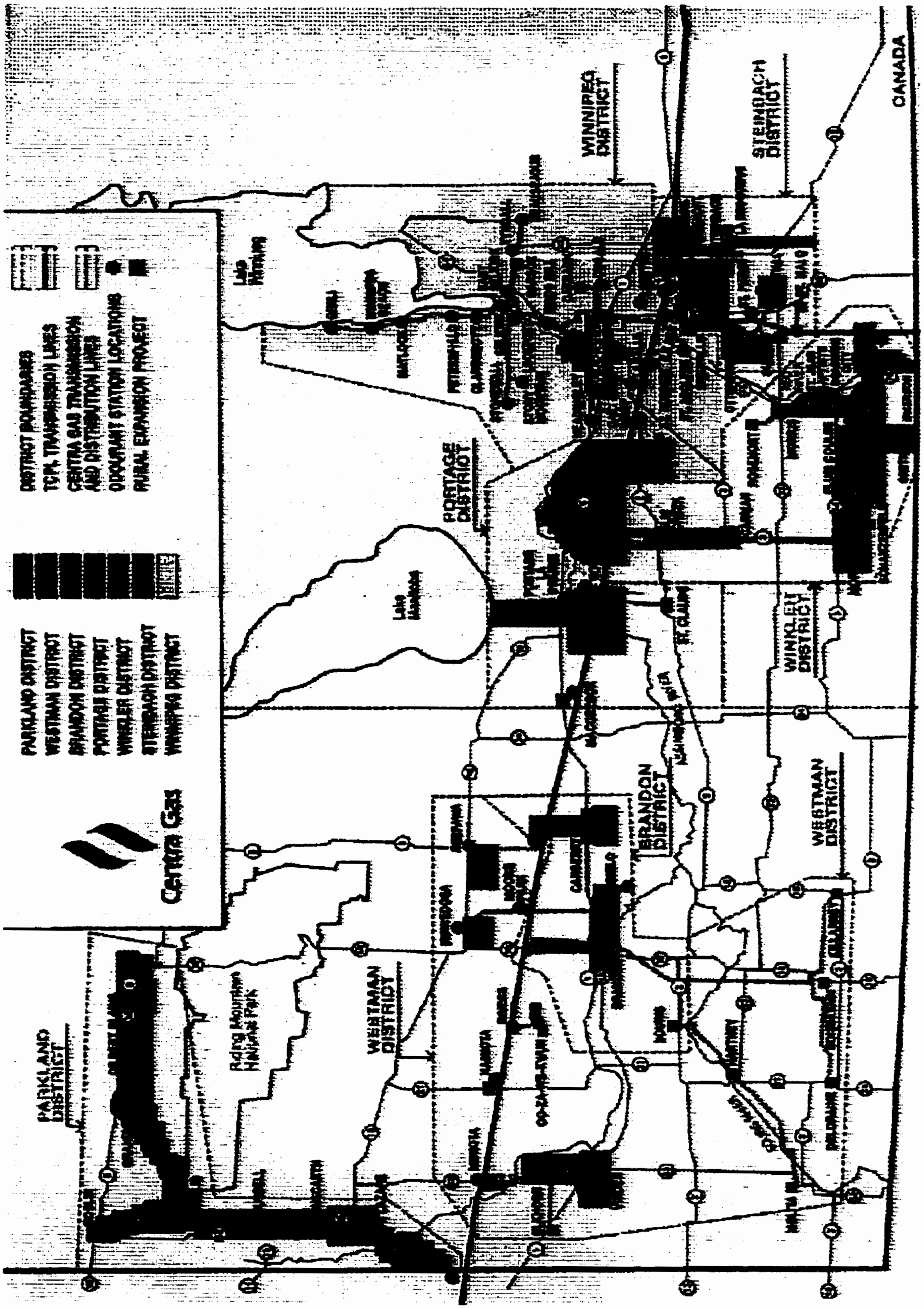
The natural gas industry is a highly regulated industry with transportation rates charged on the NOVA system regulated by the Alberta Energy Resource Conservation Board. Transportation rates charged on the TCPL portion is regulated by the NEB. Natural gas purchase rates charged to Manitoba consumers by Centra Gas are regulated by the Manitoba Public Utilities Board (Manitoba Energy and Mines, 1996).

2.5 Natural Gas as a Vehicle Fuel

2.5.1 Vehicle Conversion

Natural gas fueled vehicles are similar to gasoline fueled vehicles in that both use a four stroke spark ignition engine (Otto engine). The primary difference is the method of fuel storage and the fuel delivery to the engine. Natural gas, being a gas at ambient temperature and pressure, is at a disadvantage when compared to gasoline. Because gasoline is stored as a liquid, its energy density per unit volume is considerably greater than a comparable volume of

Figure 1 Distribution of Natural Gas in Manitoba



Source: Centra Gas Manitoba Inc.

natural gas at atmospheric pressure. A given volume of gasoline contains about 960 times as much energy as an equal volume of natural gas. In order to be able to store enough natural gas to travel a reasonable distance before refueling, it is necessary to compress natural gas under pressures from 2,600 - 3,500 pounds per square inch (17,240 kilopascals - 20,690 kilopascals) to reduce bulk (Heath, 1991). Natural gas is stored in high pressure steel or composite cylinders attached to the vehicle.

There are various methods to convert a vehicle to operate on natural gas (Appendix B contains detailed information on vehicle conversions required to operate using natural gas, vehicle performance and maintenance). Both carburated vehicles and vehicles equipped with electronic fuel injection can be converted to operate using natural gas with only minor conversion differences.

Converting a vehicle to operate using natural gas also requires the installation of high pressure fuel lines, a pressure regulator, an air-fuel mixer, a compressed natural gas filling connection and a fuel selector switch which enables the driver to choose between natural gas and gasoline (Natural Resources Canada, 1996). The installed cost of a natural gas school bus conversion in Manitoba varies between $4,750 and $5,500 (plus applicable taxes) and is dependent on the number of steel storage tanks required (Turner, personal communication).

School buses converted to use natural gas typically experience a 10 percent reduction of engine power as compared to gasoline operation (Lyons and McCoy, 1993). Maintenance expenses for vehicles converted to use natural gas are about the same as compared to non-converted vehicles (Lyons and McCoy, 1993).

The conversion of vehicles to use natural gas as a vehicle fuel is a proven technology. In fact, some automotive manufacturers now certify certain conversion operations and equipment and carry the same warranties as gasoline fueled vehicles (Natural Resources Canada, 1996).

2.5.2 Refueling

There are three basic methods to refuel natural gas fleet vehicles: fast-fill stations; time-fill stations (with an option for some fast-fill capacity); and, mother-daughter stations. The optimal refueling system for fleet applications depends on the number of vehicles to be filled, the volume of natural gas required, the fleet driving characteristics and vehicle refueling patterns (Lyons and McCoy, 1993).

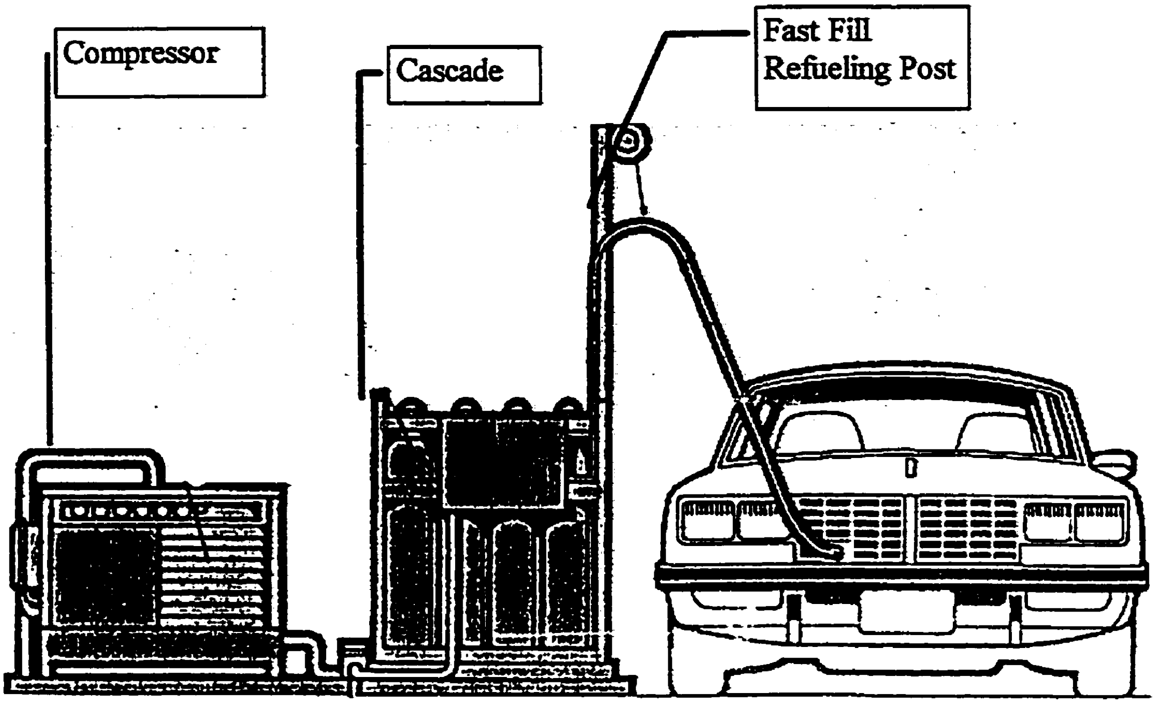
A fast-fill station refuels vehicles from high pressure storage cylinders charged with compressors connected to a natural gas pipeline. A fast-fill station takes about the same amount of time to fill a vehicle as filling with gasoline. This system can refuel up to four vehicles at once, depending on the compression and storage capacity (Lyons and McCoy, 1991). However, a fast-fill system cannot be used for extended periods due to limited compressor capacity (depending on compressor capacity and storage). Therefore, refueling a fleet of vehicles must be spread out during the working day.

Fast-fill stations require high pressure cylinders and powerful compressors. Therefore, they are the most expensive system to install and are typically used in locations where buses are not centrally stored. Centra Energy Services has indicated that fast fill stations for school bus operations typically cost between $250,000 and $500,000, depending on the required volume of natural gas and the refueling schedule. Figure 2 presents a typical fast fill station.

Time-fill stations can refuel many buses simultaneously but require significantly longer to complete the refilling process than fast fill stations. The actual time to refuel varies significantly depending on the number of buses being refueled and the volume of storage in each vehicle (Sypher:Mueller, 1991). This results in fueling times between 20 minutes and 6 hours, making this type of fueling system useful in situations where vehicles are centrally parked for extended periods overnight or during the day. Depending on fleet size and refueling requirements, costs for time fueling stations range from $160,000 to $330,00 (Turner, personal communication). Figure 3 presents a typical time fill station.

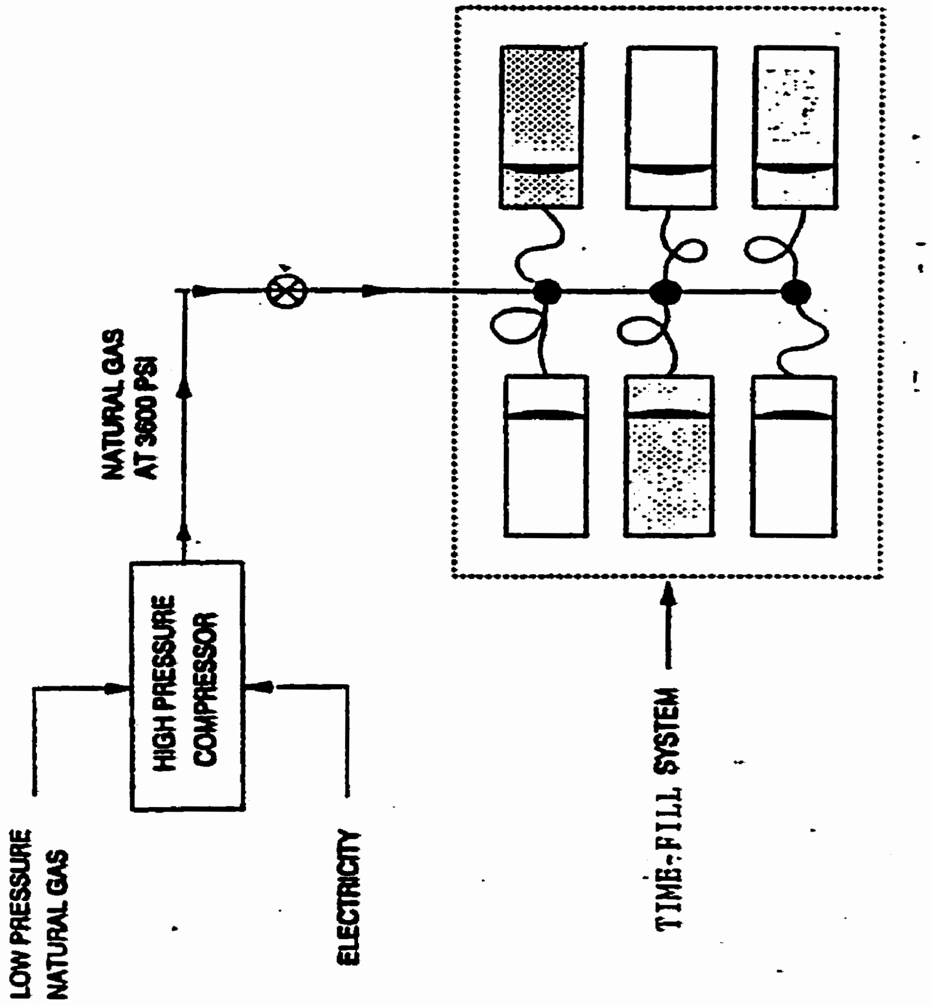
Another alternative type of refueling system is the "mother - daughter" system. In this system, large natural gas tanker trucks are filled from a single large capacity compressor station. Once loaded, these trucks proceed to the fleet base where a distribution system has been built. Instead of being fueled from the slow fill compressor fed by the underground distribution system, fuel is supplied from the tanker truck (Sypher:Mueller, 1991). However, as this system is not currently available in Manitoba, it is not a viable consideration for school division conversions (Turner, personal communication).

Figure 2: Fast-Fill Station



Source: Mueller Associates Inc., 1986

Figure 3: Time-Fill Station



Source: The Natural Gas Vehicle Coalition, 1990

Standards for the components and installation natural gas refueling systems are set out by the Standards Council of Canada and the Canadian Standards Association. Storage tank standards are published in Canadian Standards Association document B51-M1991 and relevant references. The standards for other components and installation of a natural gas refueling systems are published in the Canadian Gas Association document CAN/CGA-B149.4-M91 and relevant references. Manitoba has adopted these documents through legislation as the provincial standards for natural refueling stations. The Manitoba Department of Labour enforces the application of these standards (Weekes, personal communication).

2.5.3 Vehicle Emissions

One of the important advantages of using natural gas as vehicle fuel is the environmental benefits associated with reduced tailpipe emissions. Of the various tailpipe emissions resulting from the combustion process, the compounds typically evaluated include total hydrocarbons (THC), non-methane hydrocarbons (NMHC), carbon monoxide (CO), nitrogen oxides (NOx) and carbon dioxide (CO_2). Using different fuels in an engine result in varying emission levels for the five noted compounds. If an engine were to completely consume the fuel in the combustion chamber, a complete burnout of exhaust by-products would occur with resulting low CO and HC emissions (Lyons and McCoy, 1991).

The typically evaluated compounds result in environmental impacts by either contributing to global warming or degrading local air quality. Global warming is the process by which higher concentrations of "greenhouse gases" trap greater amounts of heat in the atmosphere. This results in higher atmospheric temperatures as well as changed weather patters and ocean circulation (Environment Canada, 1993). Degraded local air quality relates primarily to the occurrence of ground level ozone and urban smog that occurs when certain compounds in the atmosphere undergo photochemical changes (Environment Canada, 1993).

One major concern is ground level ozone, which is a product of reactive hydrocarbons (such as aliphatic olefins, aldehydes), nitrogen oxides and ultra violet radiation. Ground level ozone has been linked with reduced lung capacity and premature aging as well with decreased agricultural yields and reduced forest growth (Sypher:Mueller, 1991). Ground level ozone produces the lung searing feeling associated with smog. Non-methane hydrocarbons are one of the primary sources of urban smog. Nitrogen oxides are thought to be a contributor to acid rain and ground level ozone in urban areas (Wilkinson, 1990).

The different chemical compositions of natural gas and gasoline results in these two fuels produce differing tailpipe emissions. However, it must be noted that natural gas dual fuel conversions are operated in an engine designed specifically to operate using gasoline. This limits the potential for emission reductions resulting from using natural gas. Furthermore, emission control systems are also designed to operate in a gasoline environment, which adds further limitations to the potential emissions reductions (Lyons and McCoy, 1991).

Measuring vehicle emissions is a very difficult process and producing reliable results is complex. As a result of the numerous variables that affect the production of tailpipe emissions, tests performed on the same engines, in the same vehicles, and under the same conditions will produce varying results (Heath, 1991). Therefore, the emission results from one type of natural gas dual fuel conversion can vary significantly depending on the vehicle on which it is installed. Actual results in the real world will vary by a greater degree as a result of additional variables such as the way a driver accelerates and brakes (Heath, 1991). For this reason the results from lab tests of vehicle emissions can at best be considered suggestive rather than absolute.

Another factor affecting the emissions from an engine converted to natural gas dual fuel is the type of conversion kit installed on the vehicle. One type of conversion kit is the "open loop" mechanical air-fuel metering and mixing system. This system relies on a venturi and piston type valve and therefore results in higher emissions because it cannot adequately respond to changes in engine speed. As well, the fact that the mechanism tends to drift out of tune as a result of friction, wear and sticking further results in higher emissions (Lyons and McCoy, 1991). The other type of conversion kit is the solid state electronic gaseous fuel injection system. This system uses sensor feedback and engine computer control systems to provide an optimum fuel to air mixture and therefore produces fewer tailpipe emissions.

Due to the above mentioned issues affecting the measurement of tailpipe emissions, published emissions analyses have produced contradictory results even between test vehicles is a study. In one study of natural gas dual fuel conversions, nitrogen oxide emissions were found to be higher for three of eleven converted vehicles and were as much as 50% less for several vehicles (Lyons and McCoy, 1993). Increased nitrogen oxide levels may result from higher engine temperatures and excess oxygen available for combustion (Weekes, personal communication). A United States Environmental Protection Agency (EPA) study found that NOx emissions may increase (approximately 42 per cent) with natural gas as a result of advancing the spark timing (Sypher:Mueller, 1991). Advancing the spark timing is often used to compensate for the slower flame speed of natural gas and thus improve vehicle performance (Sypher:Mueller, 1991).

A study prepared by Sypher:Mueller International (1991), reports that EPA tests indicated that dual fuel light duty vehicles operated on natural gas can offer a significant reduction in CO emissions (0.1 - 1.7 grams per mile) compared with operation on gasoline (1.3 - 9.8 grams per mile) This reduction is attributed to more uniform air-fuel mixing when using natural gas.

When considering emissions changes resulting from vehicle conversion to natural gas, it is important to test the impact on vehicles before and after conversion. This will assure that emissions are in fact lower for vehicles after conversion. To verify emissions reductions from converted vehicles, Mountain Fuel Supply conducted urban driving cycle tests on 11 converted CNG vehicles (Lyons and McCoy, 1993). The test combined seven light duty trucks (1979 through 1991) and four automobiles (late model) with a mix of two and four barrel carburetors, throttle body fuel injection and port fuel injection systems. Table 3 summarizes the Mountain Fuel Supply test results:

Table 3: Emissions Attributable to Natural Gas and Gasoline Fueled Vehicles*

Emissions (grams per kilometre)	Natural Gas	Gasoline	Emissions Reduction	Percent Reduction
Total Hydrocarbons (THC)	0.936	0.426	+0.510	+120%
Non-Methane Hydrocarbons (NMHC)	0.021	0.064	0.043	67%
Carbon Monoxide (CO)	0.257	4.411	4.154	94%
Nitrogen Oxides (NOx)	0.867	1.036	0.169	16%
Carbon Dioxide (CO_2)	278.135	356.532	78.397	22%

* Lyons and McCoy, 1993

As can be seen in the table, CO and CO_2 emissions are significantly less for natural gas vehicles as compared to gasoline vehicles. NOx and NMHC emissions are also less for natural gas vehicles versus gasoline vehicles. THC emissions are however significantly greater for natural gas vehicles. As natural gas is composed primarily of methane, any unburned fuel from the combustion process comes out of the tailpipe as methane. As most of the THC is composed of methane, it does not contribute to ozone formation (Sypher:Mueller, 1991). As a greenhouse gas however, methane is approximately four times more effective than CO_2 (Environment Canada, 1993). This partially offsets the benefits of reduced CO_2 emissions from natural gas conversion.

2.6 Natural Gas Vehicle Safety

Safety when transporting children is a very important issue for parents, school boards, fleet administrators and government officials. For a new technology to be accepted for widespread application, it is necessary that it be as safe as, or safer than, current and expected future technologies. According to Heath (1991), with over 500,000 natural gas vehicles on the road worldwide, there have been no reported deaths directly attributed to the use of natural gas. Several of the characteristics of natural gas in fact make it a particularly safe vehicle fuel in situations of collision or accidental release. Being less dense than air, natural gas quickly disperses when released in open areas rather than pooling and causing an explosion hazard. As well, with a higher autoignition temperature than gasoline or diesel fuel, the risk of fire is significantly less (Heath, 1991).

Probably the largest safety concern however, is the possibility of a rapid release of natural gas from a storage tank, explosion of a storage tank or an accident during the refueling process. This concern has compelled storage tank manufactures to produce tanks that have been tested in crashes, explosions, and drop tests. It is likely that licensed natural gas vehicle tanks are one of the safest components on a vehicle (Heath, 1991). In Canada, natural gas vehicle storage tanks must meet a standard (please refer to Appendix A for natural gas conversion standards) that requires design pressures that considerably exceed the pressures needed in service (Natural Resources Canada, 1996). To release tank pressure in the case of fire, tanks are fitted with "melting plugs" that vent gas at a preset temperature (Sypher:Mueller Associates, Inc., 1986). This prevents the pressure in the tank from increasing to the point where tank failure may occur.

In a New York State dual-fuel school bus demonstration project that took place between 1983 and 1986, there was no difficulty with natural gas storage on vehicles (Sypher:Mueller Associates, Inc., 1986). It was indicated however that the quality of the installation is important. The report recommends that a professional engineer should be retained to inspect the installations.

As part of the 1990 EPA evaluation of the safety of natural gas as a vehicle fuel, "expert projections" were used to assess the safety of natural gas in comparison to gasoline or diesel fuel (Lyons and McCoy, 1991). Table 4 compares the result of the projections:

Table 4: Selected Safety Issues for Natural Gas and Gasoline

Safety Issue	Natural Gas	Gasoline
Toxicity	Non toxic, however it is an asphyxiant.	Toxic if ingested or inhaled, suspected carcinogen.
Flammability	Lower risk than gasoline, higher risk in closed areas.	High risk, particularly in closed areas.
Fire Hazard	Fire confined to leak site, no smoke.	Burns rapidly, produces smoke.

The assessment of natural gas compared to gasoline in the above table indicates that natural gas is less toxic and has a lower risk of igniting. As well, in the event of natural gas igniting as a result of a leak, the fire is confined to the leak source and will not spread. Gasoline by comparison has a greater risk of igniting and spreading due to it being a liquid.

2.7 Other School Bus Fuel Options

Besides natural gas and gasoline, school buses can be fueled with diesel fuel or propane. Methanol and ethanol are other alternative fuels that are also being used as vehicle fuels in North America. Evaluations of these fuels are included in this research as it is recognized that fleet managers require information on other fuels to assist the decision making process. However, conducting fleet level economic and emissions analysis for these other school bus fuel options is beyond the scope of this report. Evaluations of the other school bus fuel options are located in Appendix B.

2.8 The Natural Gas Conversion Decision

School bus fleets provide an excellent opportunity for the use of natural gas as an alternative transportation fuel. School bus fleets are good subjects to evaluate the feasibility of natural gas as a vehicle fuel for several reasons. Many school bus fleets already have on-site natural gas service at storage or maintenance compounds. Having on-site natural gas service means that extending piping to filling stations is a relatively inexpensive addition.

A second reason why school buses are good candidates for conversion to natural gas is that many divisions store buses overnight on division property. This allows buses to be refueled during stand-down periods (and eliminates the need to install individual compressors for each bus at overnight storage sites).

The third reason school buses provide excellent opportunities for using alternative fuels is that buses usually have closed loop usage. This means that buses usually travel the same route every day which rarely goes beyond the range of a full natural gas fuel load. Finally school bus fleets maintain complete records on distance traveled and fuel consumption which ensures accurate base line data.

2.8.1 Converting Existing Buses

The current provincial policy is to use school buses for thirteen years regardless of the odometer reading. While this study takes the approach of examining the overall feasibility of converting all the buses in a school division, in most cases it would be impractical from a logistical point of view to convert all the buses at once. A multi-year implementation process would examine each bus in detail to determine those buses to be initially converted and those to be undertaken later.

2.8.2 Converting New Buses

Obviously, the greatest potential economic benefit would be derived by converting new replacement school buses. Any additional buses purchased by school divisions can be immediately converted with a natural gas dual fuel conversion kit. Purchasing decisions can be made with this in mind and buses chosen that are known to be amenable to such conversions. Certain school divisions have indicated that there is a preference to purchase new buses with diesel motors instead of gasoline because of fuel cost savings, durability and ease of repair. As diesel buses are not economical to convert to dual fuel, this would greatly limit the number of buses that may be converted.

CHAPTER 3

EVALUATING THE FEASIBILITY OF NATURAL GAS CONVERSIONS

3.1 Introduction

This chapter presents and demonstrates the methodology for evaluating the economic feasibility and the effect on tailpipe emissions from using natural gas as a vehicle fuel in school bus fleets.

It must be stressed that this analysis represents a primary level analysis that is intended to indicate those school divisions where it may be feasible to use natural gas as a vehicle fuel. The results of this analysis should not be used as the sole basis for decision making, but instead provides direction as to the need for additional detailed analysis and the development of an implementation plan.

3.2 Economic Assumptions

Analyzing the economic feasibility of using natural gas as a vehicle fuel is dependent on the vehicle use characteristics and the economic and technical assumptions of vehicles using natural gas. Accordingly, the following variables will be examined and the assumptions used for the purpose of the analysis, discussed:

- Fuel prices
- Fueling facility construction
- Fuel efficiency

- Dual fuel conversions
- School bus conversion costs
- Operating costs
- Training expenses
- Gasoline fueled buses
- Division owned buses
- Period of analysis
- Maintenance savings
- Taxes
- Fraction of time using natural gas
- Salvage Value
- Energy Conversion.

The following is a brief discussion of the assumptions used in the economic analysis of using natural gas as a vehicle fuel in Manitoba school bus fleets.

1. Fuel Prices

School bus fleets can be expected to reduce fuel expenses by converting to natural gas because the price of natural gas is less than gasoline on an energy equivalent basis. The amount of savings is dependent on the price difference between natural gas and gasoline. Some Manitoba school divisions enter into bulk supply for gasoline to take advantage of lower priced bulk purchases. Those school divisions that do not enter into bulk purchase agreements will pay varying prices throughout the year at the retail pump. For the purpose of this analysis, the average price for gasoline for the 1995/96 school year was used. This information was provided by school divisions as part of the completed survey questionnaire used to gather information for this study.

The current price (February 1997) of natural gas was provided by CES and expressed as a unit of gasoline equivalent. The unit of gasoline equivalent is the unit volume of natural gas with the energy equivalent of a litre of gasoline. As school divisions may enter into natural gas purchase agreements with natural gas brokers, the potential may exist to purchase natural gas at lower rates than are available through CES. For the purpose of analysis, the price of natural gas was assumed to be the CES price.

Based upon discussions with representatives with Natural Resources Canada, it was assumed, that for the purposes of this analysis, the price difference between natural gas and gasoline would remain constant in real terms.

2. Fueling Facility Construction

A significant part of the cost of converting a vehicle fleet to use natural gas is the cost of the refueling facility. The cost of refueling facilities is dependent on the volume of natural gas required, the fueling rate and the specific site characteristics. Determining the optimal fueling facility design would require a detailed engineering evaluation of each school division's property, fleet size and fuel consumption. This was beyond the scope of this feasibility analysis.

For the purpose of this analysis, the refueling facilities were designated as small, medium or large. School divisions were assigned a small refueling station if the annual gasoline litre equivalent of natural gas consumption was between 0 and 80,000 litres.

Medium refueling stations were assigned to school divisions if the annual gasoline litre equivalent of natural gas consumption was between 80,001 and 250,000 litres. Large refueling stations were assigned to school divisions is the annual gasoline litre equivalent of natural gas consumption was in excess of 250,001 litres. All refueling facilities were assumed to be slow fill stations to minimize facilities' costs. For those school divisions already using natural gas as a vehicle fuel for part of their fleets, only the incremental cost to upgrade the compressor was considered. Refueling facilities costs were provided by CES.

CES indicated that the useful life of the compressor used in a refueling facility is fifteen years. It was further indicated that there is no salvage value associated with a compressor once its useful life has ended.

3. Fuel Efficiency

The fuel efficiency of converted vehicles cannot be determined before conversion. Theoretically, an engine designed to operate on gasoline should be less efficient when operating on natural gas. This occurs because the engine has been optimized to operate on gasoline, not natural gas. It has been suggested that the cleaner and evenly burning characteristics of natural gas makes up for the reduction in efficiency. However, for the purposes of this analysis, it was assumed that there was a natural gas efficiency penalty. This issue is discussed in greater detail in section Appendix A.

Since diesel fuel engines attain higher thermal efficiencies than gasoline engines, it was assumed that a fuel efficiency loss is added in the conversion to an equivalent gasoline volume (Arbez, personal communication).

4. Dual Fuel Conversions

School divisions desire flexibility in how they operate their fleets. At times they may wish to operate school buses on trips where natural gas vehicle fuel is not available. However, during regular route operations, school buses would use natural gas almost exclusively. Fleet conversions thus far in Manitoba have been completed as dual fuel conversions with vehicles able to use either natural gas or gasoline. Therefore, this research assumed conversions were based on the dual fuel option using natural gas and gasoline.

5. School Bus Conversion Costs

The cost of converting school buses to natural gas is relatively fixed per conversion. Differences in conversion costs depend on the number of storage tanks installed on the school buses. However, to allow flexibility in their fleet operations, it was assumed that all converted school buses were equipped with the same number of storage tanks. This research assumed conversion costs supplied by CES.

6. Operating Costs

Operating costs for refueling facilities includes both electricity costs to operate the compressors and maintenance costs. As these costs are a function of the volume of natural gas flowing through the refueling facility, operating costs can be expressed as cost per litre gasoline equivalent. The gasoline litre equivalent is the price for an amount of natural gas with the energy equivalent to of a litre of gasoline. Operating costs were supplied by CES and include all labour and materials.

Discussion with Manitoba Hydro indicated that the real price of electricity in Manitoba should remain constant until at least the year 2006 (Kristjanson, personal communication). The electricity cost portion of the operating costs was therefore assumed to be constant over the analysis period. Based on discussions with CES, maintenance costs were also assumed to remain constant through the period of analysis (Turner, personal communication).

7. Training Expenses

Training expenses represent the cost to train mechanics, drivers and other relevant personnel to use natural gas as a vehicle fuel, maintain vehicles and refueling facilities, and safety training and procedures. As the cost is relatively fixed regardless of the fleet size, a fixed value was used for all school division conversions. The training provided by CES includes five hours of training for mechanics and two and a half hours training for drivers and other support staff. Training expenses were provided by CES.

8. Gasoline Fueled Buses

Only those buses currently using gasoline were included in the research. Diesel fuel buses would require extensive engine modifications to use natural gas. As current code dictates that propane vehicles must be dedicated conversions, propane fueled vehicles would be required to be reconverted to use gasoline, and then to natural gas dual fuel (natural gas and gasoline). At the present time these, modifications would be prohibitively expensive for school divisions (Weekes, personal communication).

It is further assumed that school divisions are able to trade diesel fueled school buses with school divisions that do not have access to natural gas. This allows school divisions to maximize the number of vehicles that may be converted to use natural gas. The Manitoba Department of Education was contacted regarding this assumption. The Director responsible for pupil transportation indicated that school divisions may trade school buses with other school divisions at their discretion (Hanson, personal communication).

9. Division Owned Buses

Several school divisions do not own a portion of the buses used for their fleet operations. Buses not owned by the school divisions are contracted out from individuals or companies and are paid at a flat rate for the number of kilometres traveled. As school divisions do not own contracted school buses, they have no influence on the fuel choice for these vehicles. For purposes of this analysis, contracted buses were not included.

10. Period of Analysis

School buses are retired in Manitoba after thirteen years of use (Hanson, personal communication). The period of analysis is therefore assumed to be thirteen years.

11. Maintenance Savings

Potential savings that may be realized as a result of reduced maintenance costs are difficult to quantify due to the unique vehicle characteristics of each division. As well, sources reviewed fail to indicate that maintenance savings can be expected for all conversions. Further discussion of this issue can be found in Appendix A. It was assumed that maintenance savings are nil.

12. Taxes

As of February 1997, gasoline sales in Manitoba were subject to the provincial road tax of 10.5 cents per litre, the federal gasoline excise tax of 3.5 cents per litre and the federal Goods and Services Tax (GST) of 7 percent. Natural gas purchases, as well as other capital expenditures, are subject to the provincial sales tax of 7 percent and the federal GST for a total tax incidence of 14 percent.

Public sector institutions, such as school divisions, are permitted a partial rebate of the GST. This results in a total combine provincial and federal tax incidence of 9.24 percent. Natural gas for use as a vehicle fuel and other expenditures were subject to the reduced tax incidence in the analysis. Gasoline prices provided by the school division questionnaire included applicable taxes.

13. Fraction of Time Using Natural Gas

As indicated in Appendix A, vehicles converted to use natural gas as a dual fuel do not use natural gas at all times. Gasoline is used periodically, to ensure that fuel system elastomer components are maintained, and when trips exceed the natural gas vehicle storage range. Discussions with the Seven Oaks School Division indicated that natural gas was used approximately 90 percent of the driving time. For purpose of this analysis, it was assumed that school divisions use natural gas 90 percent of the driving time.

14. Salvage Value

The two potential sources of salvage resulting from school division conversion are the school bus conversions and the refueling facility. Discussions with CES indicated that school buses converted to operate using natural gas do not result in an incremental salvage value upon disposal. Furthermore, the refueling facility has no salvage at the end of its useful life.

However, as the period of the analysis was assumed to be thirteen years but the refueling facility has a useful life of fifteen years, there is a salvage value associated with the remaining useful life of the refueling facility. For purpose of analysis, it was assumed that the salvage value of the refueling facility represents two years' straight line depreciation.

15. Energy Conversions

Because different vehicle fuels are composed of different compounds, the energy content for equivalent volumes of these fuels is different. This means that equivalent volumes of natural gas, gasoline and diesel have different energy contents. To determine the volume of gasoline required to replace diesel fuel buses and the volume of natural gas required to replace gasoline, fuels must be converted to their energy equivalents. Assumptions used for these conversions are found in Appendix D.

3.3 Emissions Assumptions

Vehicle testing indicates that using natural gas as a vehicle fuel result in reduced tailpipe emissions compared to gasoline. The degree of the reduction in tailpipe emissions however, varies significantly depending on the test methodology, type of vehicle and engine used, test conditions and other variables (Heath, 1991). As a result of variations in test results and the fact that no test results for school buses have been located, the emissions reductions that can be obtained by individual school divisions may at best be considered an estimate.

The tailpipe emission compounds addressed by this research include total hydrocarbons (THC), non-methane hydrocarbons (NMHC), carbon monoxide (CO), nitrogen oxides (NOx), and carbon dioxide (CO_2). Tailpipe emissions are commonly expressed as grams per mile or kilometre.

For purpose of this analysis, the results of emission testing by Mountain Fuel Supply as indicated in Lyons and McCoy (1993) will be used to determine potential emissions reductions. This test procedure was chosen because it is based on before and after conversion emissions on a wide cross section of trucks and automobiles with various engine sizes and fuel delivery systems. The emission assumptions used in this analysis are detailed in Section 2.5.3

3.4 Economic Analysis

The economic feasibility of adopting natural gas as a vehicle fuel in Manitoba school bus fleets was assessed using the net present value (NPV) of the project as well as the net annualized savings. This analysis was prepared on a Microsoft Excel spreadsheet for each school division. This permitted sensitivity calculations for various factors affecting the analysis.

The economic feasibility of school bus fleet conversions to use natural gas as a vehicle fuel was assessed by determining if the costs of converting vehicles and building and maintaining the refueling facility is offset by fuel cost savings of using natural gas. The economic analysis was performed from the perspective of the school divisions and therefore included only those benefits and costs incurred by school divisions.

It may be argued that as school divisions are public sector institutions, the benefit and cost analysis should take into account all societal benefits and costs that accrue, rather than the narrowly defined objectives of school divisions. This approach was rejected based on the rationale that school divisions make decisions solely on the impacts to their budget and do not take into account wider societal impacts. If the analysis was taken from the perspective of the provincial or federal governments, the use of a societal benefit and cost analysis would have been more appropriate.

Data for individual school divisions' bus fleet characteristics were obtained by a survey questionnaire sent to school division Transportation Supervisors. A copy of the questionnaire is found in Appendix C. School divisions with access to natural gas were contacted to invite their participation in the research. However, as participation in this research was voluntary, not all school divisions were willing to participate in the research. As well, certain school divisions did not provide the requested data in sufficient time to be included in the research.

The first step after the data was gathered was to enter the data into the 'Data' worksheet on the spreadsheet. As indicated in the assumptions, diesel fueled buses were assumed to be traded for gasoline buses in other divisions. This required the conversion of diesel fuel consumed to an energy equivalent volume of gasoline (values for energy conversion are located in Appendix A). Since diesel fuel engines attain higher thermal efficiencies than gasoline engines, a ten percent fuel efficiency loss was added in the conversion to an equivalent gasoline volume (Arbez, personal communication). Diesel fuel was converted to an equivalent gasoline consumption using the following formula:

$GC = (DFC * DFLHV) / ((1-TE) * GLHV)$

where

- GC is the gasoline consumption in litres
- DFC is the diesel fuel consumption in litres
- DFLHV is the lower heating value of diesel fuel (36.40 megajoules per litre)
- TE is the thermal efficiency penalty for gasoline engines as compared to diesel fuel engines (0.1), and
- GLHV is the lower heating value of gasoline (32.40 megajoules per litre).

The next step was the calculation of the total volume of natural gas required to substitute the gasoline consumption by the school bus fleet. As this analysis determined the overall feasibility of using natural gas for a school division, all gasoline fueled school buses were considered candidates for conversion regardless of the age of the vehicle.

The calculation of the total volume of natural gas required was used to calculate the appropriate size of refueling facility. In order to calculate the substitution volume of natural gas for gasoline, the total gasoline consumption was first multiplied by its energy content of 32.40 megajoules per litre to produce the total amount of energy required (please refer to Appendix D for sources). The total energy required was then converted to a volume of natural gas by dividing the required energy by the lower heating value of natural gas (33.40 megajoules per litre).

As it was assumed that buses are operated on natural gas only 90 percent of the driving time, the total required volume of natural gas was adjusted to reflect this assumption. It was also assumed that there was a 10 percent fuel economy penalty while operating on natural gas. The total volume of natural gas required was also adjusted to take into account this assumption.

The next step was the calculation of the total annual fuel cost savings for each vehicle from using natural gas as a vehicle fuel instead of gasoline. The annual savings for each converted school bus was calculated with the following formula from Taylor et al. (1992):

$S = (GFC*PG-(NGK*NGE*PNG)-((1-NGK)*GE*PG))*K$

where

- S is the total annual savings for each vehicle (in dollars);
- GFC is the gasoline fuel consumption for the vehicle prior to conversion (in kilometres per litre);
- PG is the price of gasoline (in dollars per litre);
- NGK is the fraction of total annual kilometres driven on natural gas (a figure between 0 and 1);
- NGE is the natural gas fuel efficiency (in gasoline litre equivalents per kilometre);
- PNG is the price of natural gas (in gasoline litre equivalent);
- GE is the gasoline fuel efficiency (in litres per kilometre); and,
- K is the annual distance traveled by the school bus (in kilometres).

The savings for each school bus dual fuel conversion is then summed for the entire fleet to produce the total annual fleet savings. As each bus exhibits unique fuel efficiency characteristics, this model accounts for differences between vehicles. The results of these calculations are then used as input into the 'Analysis' worksheet that performs the economic and emissions analysis.

The 'Analysis' worksheet calculated the net present value of the project as well as the net annualized savings of the project. The economic analysis portion of the worksheet was divided into three sections: 1) Costs; 2) Savings; and, 3) Present Value and Net Annualized Savings.

The Costs section recorded all costs associated with the conversion of the school bus fleet and made the following calculations:

Conversion Costs:	Conversion costs were calculated by multiplying the number of school buses to be converted by the conversion cost per school bus.
Refueling Facility:	The cost of the refueling facility was determined by the annual volume of natural gas required for the conversion fleet. As the refueling facility has an effective life of 15 years while the period of analysis is 13 years, there remained an unused portion of this capital expense. This unused portion of the value of the refueling facility is considered as a salvage value. The salvage value is calculated by multiplying the capital cost of the refueling facility by the percentage of useful life remaining to determine the straight line depreciation.
Training Expenses:	The training expenses associated with school bus fleet conversion is treated as a constant value. This figure was supplied by CES.
Operating Expenses:	Operating expenses are comprised of electricity to operate the compressor(s) and maintenance. As these costs are a function of the annual natural gas compressor throughput, the operating expenses were calculated by multiplying the total annual gasoline litre equivalent volume by the constants for operating and maintenance expenses.
Total Cost:	The total cost was comprised of the total capital (including the present value of the salvage value) and training costs plus the present value of operating costs. The present value of the operating costs was calculated

by discounting the annual operating costs by the discount rate. The present value of the salvage value of the refueling facility was calculated by discounting the salvage value to the beginning of the analysis period.

The Savings section of the worksheet calculated the savings resulting from the displacement of gasoline. Annual fleet savings calculated on the 'Conversion Fleet' worksheet were brought forward for each year of the analysis. As the savings occur over the period of the analysis, it was necessary to express the summation of the savings as a present value. The present value of the savings was calculated by discounting the annual savings by the discount rate.

Once the total present value of project costs and discounted savings were calculated, the net present value of the project was calculated by subtracting the total project costs from the discounted savings. If the discounted savings were greater than the cost of the project, the conversion should be further analyzed to develop implementation plans.

The capital costs (refueling facility and vehicle conversion costs) and training expenses of the fleet conversion were also calculated on an annualized basis to determine the impact of financing the conversion over the period of the analysis. The annualized value was calculated using the PMT (Payment) Microsoft Excel function. This function returns the annualized value of the expense for each year at the given interest rate. As the discount rate represents the opportunity cost of money to the school division, this also represented the interest rate.

The summation of the annualized costs of capital and training and the annual operating expenses was subtracted from the annual fuel savings to determine the net annualized savings. As the annualized costs included the opportunity cost of money, the net annual savings could be a negative value while the net present value was positive. This provided school divisions the opportunity to observe the impact of financing the fleet conversion as opposed to using current funds.

The results of the economic analysis were provided on the 'Summary Results' worksheet, which detailed the assumptions used in the analysis and the results of the economic analysis. As the analysis was sensitive to the price of natural gas, the price of gasoline, the cost of conversion, the cost of the refueling facility and the discount rate, a sensitivity analysis was also conducted to determine the degree of sensitivity to these factors. Using the 'Goal Seek' tool on Microsoft Excel, the individual change in these variables required to produce a net present value equal to zero was determined. The sensitivity was expressed as the percentage change from the originally assumed value required to produce a net present value equal to zero.

3.5 Emissions Analysis

Apart from the monetary benefits that may be derived, using natural gas as a vehicle fuel result in a reduction in tailpipe emissions. As indicated earlier, tailpipe emission compounds addressed by this research include total hydrocarbons (THC), non-methane hydrocarbons (NMHC), carbon monoxide (CO), nitrogen oxides (NOx), and carbon dioxide (CO_2). The benefits associated with reduced tailpipe emissions were not assigned a monetary value in this analysis.

The emissions reductions for these compounds were calculated by subtracting the natural gas vehicle fuel emissions from the gasoline vehicle fuel emissions . The conversion fleet reduction in tailpipe emissions was calculated by multiplying the total number of kilometres driven using natural gas by the emissions reductions for each compound. The number of kilometres traveled on natural gas was calculated on the 'Conversion Fleet' worksheet by summing the annual distance traveled for each converted school bus. As it was assumed that the school buses use natural gas 90 percent of the time, the total kilometres driven on natural gas is multiplied by 0.9 to account for this assumption.

As indicated earlier, different fuels produce different levels of emissions. Since diesel fuel was different from natural gas and gasoline, the emissions from diesel fuel engines are also different. As the analysis of emissions reductions represents the potential reductions for the natural gas conversion fleet, it did not account for changes in emissions resulting from trading diesel fuel buses with gasoline buses in other school divisions. The rationale for not including these changes in emissions was that the diesel buses were still in use, albeit in other school divisions, and therefore still producing the same emissions.

The results of the reduction in tailpipe emissions were presented on the 'Summary Results' worksheet.

3.6 Time and Money

As previously noted, the costs and savings of this analysis occur at different times during the period of the analysis. The economic value of money, however, depends on the time at which it is received or disbursed. Generally, it is assumed that the value of money in the future is less than its value today. As the fuel cost savings in the analysis of conversion fleets occurs across time, there is a need to account for the opportunity cost associated with these savings to make the money value comparable.

As this analysis is undertaken from the perspective of the school division budgeting process, the discount rate chosen to account for the opportunity cost should represent the cost of capital or the borrowing rate for the school divisions. School divisions are public sector institutions, therefore this analysis assumed the government borrowing rate (February 1997 - 10 year bond rate) as the appropriate discount rate (Gibson, personal communication).

Although the government borrowing rate is lower than rates in the private market (because government has the power of taxation), it can be argued that an even lower discount rate should be used to account for the non-valued environmental benefits associated with using natural gas as a vehicle fuel. This argument is rejected by the fact there is no standard reduction in discount rates that may be applied for these benefits. The argument, while interesting, and deserving of further analysis, was beyond the scope of this analysis.

CHAPTER 4

SCHOOL BUS FLEET EVALUATIONS

4.1 Introduction

This section presents the economic and emission parameters used in the analysis of the feasibility of using natural gas as a vehicle fuel in Manitoba school bus fleets. This is followed by the presentation of the analysis results and a discussion of issues raised by the results.

4.2 Parameters for Economic Analysis

The economic analysis as described in Chapter 3 was dependent on the assumptions used for the variables. Table 5 summarizes the parameters used in the economic analysis:

Table 5: Summary of Parameters Used For Economic Analysis

Parameter	Value	Date
Gasoline Price	Dollars per litre - varies by school division[1]	1995/96 school year
Natural Gas Price	$0.1177 per litre equivalent[2]	February 1997
Vehicle Conversion Cost	($6,008.20) per vehicle[3]	February 1997
Operating Costs • electricity • maintenance	 ($0.04) per litre equivalent ($0.01) per litre equivalent	 February 1997 February 1997
Training Expenses	($750) per fleet[4]	February 1997
Refueling Facility • small • medium • large	 ($163,860) ($245,790) ($327,720)[5]	 February 1997 February 1997 February 1997
NGV Fuel Efficiency Penalty	10%	NA
Real Discount Rate	5.00%[6]	February 1997
Fuel Substitution Rate	90%	NA
Analysis Period	13 years	NA

Notes:

[1] School divisions provided gasoline prices as part of survey questionnaire. Gasoline prices included taxes.

[2] Based on raw gas price equivalent of $0.11 cents per litre (GS4 rate class) plus taxes.

[3] Vehicle conversion based on an average cost for carbureted and fuel injected engine. Vehicle conversion include four steel storage tanks and required fuel delivery components. Conversion cost includes labour. Based on a conversion price of $5,500 plus taxes.

[4] Based on two technicians each providing five hours of instruction to mechanics and 2.5 hours instruction to drivers and other relevant school division staff. Technician labour cost equals $50 per hour.

[5] Refueling facilities were assumed to be slow fill stations. The cost of a small station was based on an installed cost of $150,000 plus taxes. The costs of medium station was based on an installed cost of $225,000 plus taxes. The cost of a large station was based on an installed cost of $300,000 plus taxes.

[6] 10 year Manitoba bond rate (Gibson, personal communication).

4.3 Parameters for Emissions Analysis

As indicated in Chapter 3, there is large body of research on the reduction in tailpipe emissions resulting from vehicle conversions to operate on natural gas. For purpose of the analysis, the results of the Mountain Fuel Supply research as referenced by Lyons and McCoy (1993) were used to determine potential emissions reductions. Table 6 summarizes the parameters used in the emissions analysis:

Table 6: Summary of Parameters Used For Emissions Analysis (grams per kilometre)

Emission Compound	Natural Gas Emissions	Gasoline Emissions	Emissions Reduction	Percent Reduction
Total Hydrocarbons (THC)	0.936	0.426	+0.510	+120%
Non-Methane Hydrocarbons (NMHC)	0.021	0.064	0.043	67%
Carbon Monoxide (CO)	0.257	4.411	4.154	94%
Nitrogen Oxides (NOx)	0.867	1.036	0.169	16%
Carbon Dioxide (CO_2)	278.135	356.532	78.397	22%

4.4 Analysis Results

4.4.1 Economic Analysis

Using the economic parameters presented in 4.2 and the methodology presented in Chapter 2, the economic feasibility of natural gas conversions for participating school divisions was calculated. The detailed results of the economic analysis are presented in Appendix E. Table 7 summaries the results of the analysis:

Table 7: Summary of Economic Analysis Results By School Division

School Division	Central Storage	# of Conversion Buses	Present Value of Costs	Present Value of Savings	Net Present Value	Net Annualized Savings
Assiniboine South	Yes	14	$354,549.74	$281,815.68	($72,734.06)	($9,593.13)
Brandon	**Yes**	**33**	**$675,419.45**	**$1,001,520.88**	**$326,101.43**	**$32,248.49**
Fort Garry	**Yes**	**18**	**$400,545.44**	**$426,025.51**	**$25,480.07**	**$862.33**
Garden Valley	No	12	$346,486.56	$289,729.64	($56,756.92)	($7,892.27)
Morris - McDonald	**No**	**28**	**$464,818.30**	**$789,308.27**	**$324,489.96**	**$32,693.66**
Norwood	No	2	$179,764.05	$100,533.58	($79,230.47)	($9,667.99)
Pelly Trail	No	8	$233,502.56	$221,312.94	($12,189.62)	($2,531.10)
St. Vital	**Yes**	**23**	**$456,541.73**	**$584,667.05**	**$128,125.32**	**$11,789.51**
Total (Bolded School Divisions)	**NA**	**102**	**$1,997,324.92**	**$2,801,521.71**	**$804,196.78**	**$77,593.99**

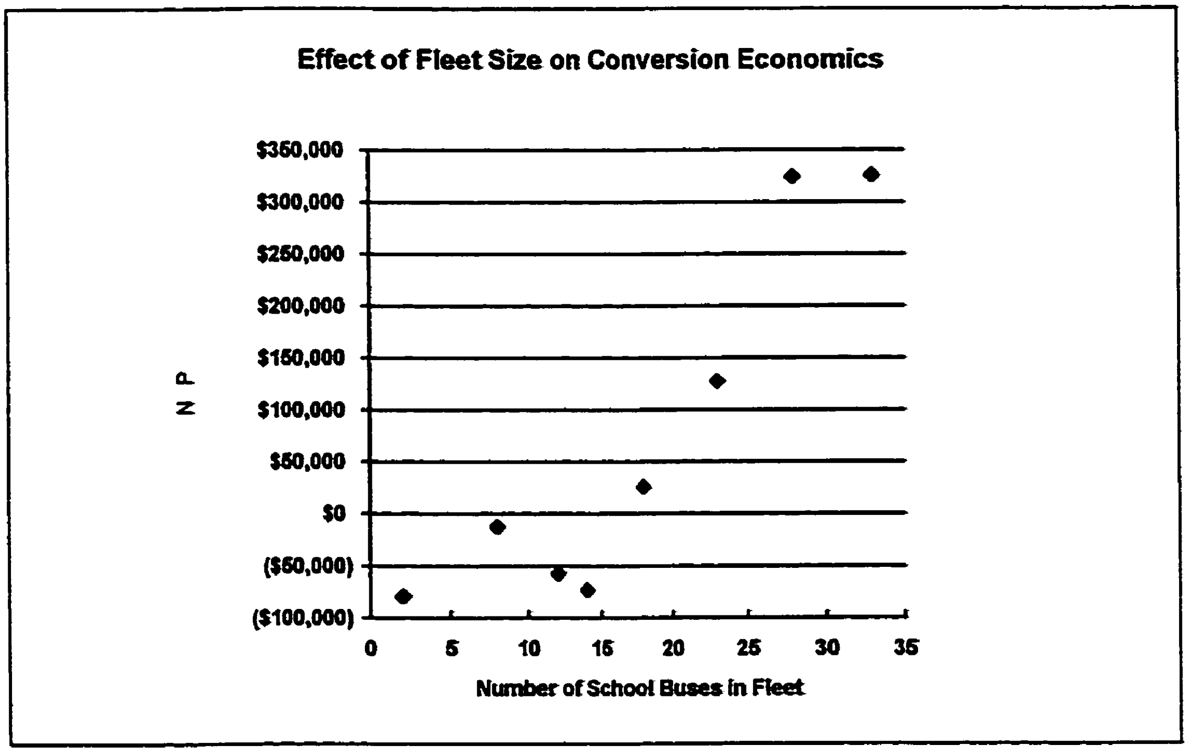
The results of the economic analysis indicated that the use of natural gas as a vehicle fuel produced positive net present values for four of the eight school divisions examined. Those divisions include: Brandon; Fort Garry; Morris - McDonald; and, St. Vital (bolded on the above table). Net present values ranged from $25,480 to $326,101 for those divisions. The values for the divisions that produced negative net present values ranged from ($79,230) to ($12,189). If conversion were to proceed for those school divisions with positive net present values, 102 buses would be converted and produce a total net present value of $804,196 over the life of the projects.

While the Morris - McDonald school division produced a positive net present value, the fact that this school division does not use centralized vehicle storage greatly limits the potential for conversion. As this analysis was based on the use of a time fill refueling facility, this division would be required to examine the feasibility of using either a more expensive fast-fill station or centralized storage. While either of these options would reduce the economic feasibility of natural gas vehicle conversion, the project net present value of $324,489 may be sufficient to offset the incremental costs of either a fast-fill refueling station or the development of centralized storage.

The four divisions that produced positive net present values also produced positive net annualized savings ranging between $862 and $32,693. This indicates that if the conversion to natural gas was financed, it would still remain an economic option for the school divisions. Although the Brandon School Division had a higher net present value than the Morris - McDonald School Division, it produced slightly lower net annualized savings. This occurred because the Brandon School Division converted five more school buses than Morris - McDonald which resulted in higher annualized costs. Those school divisions that produced negative net present values also resulted in negative net annualized savings ranging between ($9,667) and ($2,531). This result would be anticipated, since financing the conversion would produce added costs.

As can be seen from the table, the school divisions that produced negative net present values tended to have the fewest numbers of buses in their fleets, ranging between 2 and 14 buses. All the fleets that produced positive net present values had greater than 18 buses in their fleets, with one division having 33 buses. This is due to the fact that school divisions with a greater number of school buses were displacing greater volumes of gasoline with natural gas, resulting in larger fuel savings. Figure 4 demonstrates the impact of the number of school buses in the fleet on the result of the analysis.

Figure 4: Effect of Fleet Size on Conversion Economics



While it appears that a regression analysis of the data in Table 4 can be used to calculate the number of school buses required in a school division to result in a positive net present value, this would be false. As discussed in the following section, the principal factors affecting the economic analysis include the fuel price difference, the total capital cost to use natural gas as a vehicle fuel, the discount rate, and the fleet use characteristics. A multiple correlation regression model would have to be developed to predict the minimum fleet size required for the economic use of natural gas. While an interesting area for research, this is beyond the scope of this practicum.

4.4.2 Sensitivity Analysis

Once the economic analysis was completed for the school divisions, the sensitivity of the assumptions was calculated. As described in Chapter 3, the calculation determined the required changes in the variables to result in a net present value equal to zero, with all other variables remaining constant. Table 8 summarizes the calculated sensitivities as a percentage change from the original values for the school divisions:

Table 8: Summary of School Division Economic Sensitivities

School Division	Net Present Value	Natural Gas Price	Gasoline Price	Conversion Cost	Refueling Facility	Discount Rate
Assiniboine South	($72,734.06)	-75%	19%	-86%	-32%	73%
Brandon	**$326,101.43**	**91%**	**-23%**	**164%**	**107%**	**178%**
Fort Garry	**$25,480.07**	**17%**	**-4%**	**24%**	**11%**	**22%**
Garden Valley	($56,756.92)	-53%	14%	-79%	-25%	-58%
Morris - McDonald	**$324,489.96**	**117%**	**-30%**	**251%**	**138%**	**97%**
Norwood	($79,230.47)	-229%	59%	-659%	-52%	-155%
Pelly Trail	($12,189.62)	-16%	4%	-25%	-8%	-18%
St. Vital	**$128,125.32**	**61%**	**-16%**	**93%**	**56%**	**98%**

The results of the sensitivity analysis indicated that for the four school divisions that produced positive net present values (bolded in Table 8), the price of natural gas would have to rise between 17% and 117% to result in net present values equal to zero. The results also indicated that the price of gasoline would have to fall between 4% and 30% to result in net present values equal to zero. Finally, the cost of vehicle conversion, refueling facility and discount rate would have to increase by more than 100 percent for the net present value to equal zero for these school divisions. This suggests considerable leeway in the values of these variables for these projects to remain economic. However, it should be noted that the Fort Garry School Division is particularly sensitive to the price of gasoline. The price of gasoline would have to decrease by 4% for this project to become uneconomic.

Those school divisions that produced negative net present values would achieve net present values equal to zero if the price of natural gas, conversion costs, refueling facilities cost or the discount rate decreased. Alternately, increased gasoline prices would also improve the economics for these school divisions. The result of the sensitivity analysis for the Pelly Trail and Fort Garry school divisions, which are marginally uneconomic and economic respectively, indicates that small variations in the variables could make these projects economic.

The results indicate a high degree of variability in sensitivities between school divisions. This occurs because the further the net present value is from zero, the larger the change in the variables is required to produce a net present value of zero. This was demonstrated when the sensitivity results from the Fort Garry School Division and the Morris - McDonald School Division were compared. The Fort Garry School Division produced a net present value of $25,480, which would be reduced to zero if natural gas prices were 17 percent higher. The

Morris - McDonald School Division produced a net present value of $324,489 that would be reduced to zero if natural gas prices were 117 percent higher.

As well, simply comparing the size of fleets will not yield comparable results. This was demonstrated in the analyses of the Fort Garry School Division and the St. Vital School Division. As can be seen on Table 8, the sensitivities were three to four times higher for the St. Vital School Division while only operating one quarter more school buses. This results from the fact that the St. Vital School Division accumulates a total annual distance traveled of 539,000 kilometres while using natural gas while the Fort Garry School Division accumulates only 252,000 kilometres while using natural gas. Since the St. Vital School Division uses its vehicles more intensively than the Fort Garry School Division, it can absorb greater changes in the sensitivity variables.

School divisions with similar net present values also produced significantly different sensitivity values. The discount rate sensitivity for the Brandon School Division (178%) was almost twice as high as the Morris - McDonald School Division (97%) even though they produced very similar net present values. The net present value calculation used the discount rate to calculate the present value of the annual fuel cost savings over the life of the project and the present value of the salvage value. The Brandon School Division had annual fuel savings before discounting were $106,618 while the Morris - McDonald School Division had annual fuel savings before discounting of $84,028. As the Brandon School Division had annual fuel savings 27 percent higher, it would be expected to be less sensitive to changes in discount rate, as was indicated in the results.

4.4.3 Emissions Analysis

Using the emissions parameters presented in section 4.1 and the methodology presented in Chapter 3, the reduction in tailpipe emissions resulting from natural gas conversions was analyzed. The detailed summary results and emissions analysis are presented in Appendix C. Table 9 summarizes the results of the analysis:

Table 9: Summary of Tailpipe Emissions Reductions

School Division	Total Hydrocarbons (kg)	Non-Methane Hydrocarbons (kg)	Carbon Monoxide (kg)	Nitrogen Oxides (kg)	Carbon Dioxide (kg)
Assiniboine South	+859	72	7,003	285	132,174
Brandon	**+4,031**	**340**	**32,852**	**1,337**	**620,073**
Fort Garry	**+1,667**	**141**	**13,590**	**553**	**256,502**
Garden Valley	+1,081	91	8,807	358	166,226
Morris - McDonald	**+3,376**	**285**	**27,515**	**1,120**	**519,341**
Norwood	+337	28	2,744	112	51,801
Pelly Trail	+908	77	7,397	301	139,609
St. Vital	**+3,577**	**302**	**29,154**	**1,187**	**550,281**
Total Emissions Reductions (Bolded School Divisions)	**+12,651**	**1,068**	**103,111**	**4,197**	**1,946,197**

As can be seen from the above table, if those school divisions that produced positive net present values (in bold) converted their school buses to use natural gas, there would be a reduction in non-methane hydrocarbons by 1,068 kilograms, carbon monoxide by 103,111 kilograms, nitrogen oxides by 4,197 kilograms and carbon dioxide by 1,946,197 kilograms over the life of the projects. Total hydrocarbon emissions increased by 12,651 kilograms. This increase offsets the reduction in CO2 emissions since the methane portion of total hydrocarbon emissions is a greenhouse gas. As those school divisions that produced positive net present values are displacing greater volumes of gasoline with natural gas, these school divisions also produce the greatest reductions in emissions when compared to divisions that produced negative net present values.

4.5 Discussion

The results of the analysis indicated that the conversion of school buses to operate using natural gas may be economic for four Manitoba school divisions. Of those divisions that resulted in positive net present values, only the Morris-McDonald school division does not have centralized storage for its bus fleet. This poses difficulties if the Morris-McDonald school division decided to pursue using natural gas as a vehicle fuel since the analysis was based on the use of time-fill stations. Since time-fill stations can require up to six hours to complete refueling, there is a definite need for this school division to create and use a centralized storage system for its fleet.. However, given that this school division produced a net present value of $324,489, the benefits of using natural gas as a vehicle fuel may offset the cost of creating centralized vehicle storage. This would have to be taken into account upon further examination of the potential for natural gas conversion for this school division.

Of particular interest are those school divisions that are marginally economic or uneconomic. These divisions would require only relatively small changes to the sensitivity factors analyzed to affect the outcomes of the analysis. For instance, the Pelly Trail school division would produce a positive net present value if the price of gasoline increased by 4% or the cost of refueling facilities declined by 8%, with all other variables remaining constant.

As previously indicated, natural gas used as vehicle fuel is not subject to provincial road taxes. The addition of a road tax to natural gas would obviously reduce the economic feasibility of using natural gas as a school bus fuel. The current provincial road tax (10.5 cents per litre) on gasoline represents approximately 20 to 25 percent of the price of gasoline purchases. The sensitivities indicated on Table 9 suggest that three of the four school divisions that produced positive net present values can absorb the imposition of an equivalent price increase in natural gas prices. With a natural gas price sensitivity of 4 percent however, the Fort Garry School Division would be uneconomic with an increase of natural gas prices as a result of a road tax. This suggests those school divisions that were marginally economic, positive or negative, would be affected to a great degree by the imposition of a natural gas road tax.

Although natural gas is not currently taxed as a vehicle fuel, the Manitoba government may in the future decide to impose a provincial road tax on this fuel. As the economic feasibility of using natural gas as a vehicle fuel would be affected by the imposition of a provincial road tax, there is a need for a commitment from the Manitoba government of its intentions. School divisions may therefore wish to present a unified position to the Manitoba government that iterates the negative impacts of a natural gas road tax on the economic feasibility of using this fuel. In particular, a unified position would verify the positive impacts of fuel cost savings as compared to the potential revenue generation of a natural gas road tax. The goal of presenting this position to the Manitoba government would be to obtain a long term commitment that natural gas to maintain the current tax regime.

As the economic analysis used in the evaluation of the feasibility of natural gas as a vehicle fuel was based on the financial perspective of the school divisions, there has been no attempt to value the benefits and costs that may accrue outside the school divisions. In particular, there has been no attempt to value the reduction in tailpipe emissions or the reduction in fuel taxes paid to the provincial government. From a societal benefit and cost analysis approach, school divisions that are uneconomic from a strictly financial perspective may produce other positive benefits. This suggests that the provincial government may wish to undertake a benefit and cost analysis of those financially uneconomic divisions. This analysis would indicate if the use of natural gas as a vehicle fuel in school bus fleets should be supported from a societal perspective. Because the conversion to natural gas as a vehicle fuel may not be economic in all divisions, incentives may be required. This is an area for further study.

The conversion of school bus fleets, where economic, also produces several benefits for CES. The conversion of school bus fleets to use natural gas introduces the technology to the wider community, thus increasing knowledge of its use and developing acceptance. Many school divisions indicated that they were somewhat cautious of natural gas because of their lack of knowledge about its use as a vehicle fuel. As CES also intends to target the use of natural gas as a vehicle fuel to other fleets, school divisions offer the potential to demonstrate the technical feasibility and economic and environmental benefits of natural gas.

As the use of natural gas as a vehicle fuel is expanded, the costs of conversions and refueling facilities should decline. This may result in school divisions that were previously uneconomic, to become candidates for this technology. Re-examining those school divisions that were uneconomic or that had decided not to pursue the use of natural gas, may result in positive economic outcomes. With several school divisions already using natural gas as a vehicle fuel, this is already producing interest in the fuel from other school divisions. Several school divisions indicated that they were waiting to see the results from those already using natural gas before they consider using the fuel in their fleets.

Regardless of the merits or feasibility of a new technology, the way it is introduced to the users and the wider community will be a major factor in its 'success' or 'failure' (McCall, 1982). The largest factor affecting the initial acceptance of natural gas as a vehicle fuel will be the basic understanding of its use by the various stakeholders. Regarding the introduction of natural gas as a dual fuel in provincial school bus fleets, it is important to educate both drivers, mechanics and other relevant school division staff as well as the parents and students who will be traveling on natural gas fueled school buses.

For this reason, school divisions may wish to have information sessions and printed material available before the introduction of this technology. The nature of the information sessions should be tailored for each specific group. For drivers, mechanics and other relevant school division staff, the information should focus on the technical aspects of the conversion and how it will affect the use and maintenance of the vehicles. For parents, the focus of the information should be on the safety aspects, specifically citing the excellent safety record and the stringent regulations in place. Adopting natural gas as a dual fuel in provincial school bus fleets will result in administrative changes for recording fuel consumption and accounting fuel expenses.

School divisions adopting this vehicle fuel must prepare in advance for administrative changes in accounting and budgeting procedures.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Study Approach

The analysis of the feasibility of using natural gas as a vehicle fuel in Manitoba school bus fleets examined the technical feasibility and economic and environmental benefits of converting school buses to natural gas.

The economic feasibility and environmental benefits of converting school division bus fleets to use natural gas was analyzed using data collected from individual school divisions and assumptions provided by Centra Energy Services. The economic feasibility of using natural gas as a vehicle fuel in Manitoba school bus fleets was analyzed using the techniques of net present value and net annualized savings. School divisions were also tested for sensitivity to various factors affecting the economics of natural gas conversion.

The reduction in tailpipe emissions examined the change in total hydrocarbon, non-methane hydrocarbons, carbon monoxide, nitrogen oxides and carbon dioxide through the use of natural gas instead of gasoline. This was analyzed by multiplying the number of kilometres traveled using natural gas by the grams per kilometre reduction in tailpipe emissions.

5.2 Conclusions

The analysis of eight Manitoba school divisions indicated the use of natural as a vehicle fuel is economic for certain school divisions. Four of the school divisions produced positive net present values ranging from $25,480 to $326,101 The values for the divisions that produced negative net present values ranged from ($79,230) to ($12,189). For the eight fleets evaluated, a total of 102 school buses are in school divisions that produced positive net present values. Conversion of school buses within these school divisions would result in a doubling of the current natural gas school bus fleet in Manitoba.

Those school divisions that produced negative net present values would achieve net present values equal to zero if the price of natural gas, the conversion costs, the refueling facilities cost or the discount rate decreased. Conversely, increased gasoline prices would improve the economics for those school divisions.

The emissions analysis indicated that conversion of school buses to use natural gas in those school divisions where it is economic would produce an increase in total hydrocarbon emissions of 12,651 kilograms. However, the conversion would also result in reductions in non-methane hydrocarbons emissions of 1,068 kilograms, carbon monoxide emissions of 103,111 kilograms, nitrogen oxides emissions of 4,197 and carbon dioxide emissions of 1,946,197 kilograms over the life of the projects.

The review of the technical feasibility of using natural gas as a vehicle fuel for Manitoba school bus fleets indicates that it is technically feasible in terms of vehicle conversion, vehicle performance and refueling. Furthermore, the excellent safety record of natural gas as a vehicle fuel, combined with regulatory requirements, makes this fuel at least as safe as gasoline.

5.3 Recommendations

Based on the findings and analysis presented, the following recommendations are offered:

1) The following school divisions seek to develop detailed analyses and implementation plans to adopt natural gas as a vehicle fuel: Brandon; Fort Garry; Morris -McDonald; and St. Vital. These implementation plans would include issues such as a detailed engineering analysis, phase in of fleet conversions, and financing.
2) Although the Morris-McDonald school division produced a positive net present value resulting from the conversion to natural gas vehicles, its potential to adopt this fuel is limited because it does not use central storage for its fleet. The school division should examine the benefits and costs of using central storage for its fleet before making its decision.
3) School divisions should approach CES to assist in the development of a detailed analysis and implementation plan.
4) As school divisions are public sector organizations, further research into the benefits and costs from a societal perspective should be undertaken, particularly for those divisions that

are uneconomic or marginally economic. The Manitoba government is the appropriate organization to undertake this research.

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APPENDIX A

NATURAL GAS VEHICLE CONVERSION

There are various methods to convert a vehicle to operate on natural gas. Both carbureted vehicles and vehicles equipped with electronic fuel injection can be converted to operate using natural gas with only minor conversion differences. The following discussion presents only one basic type of dual fuel conversion technology. Other conversion technologies include gaseous fuel injection and variations of this approach involving feedback loops to reduce emissions and improve performance.

Figure 5 presents a typical natural gas conversion. The typical components of a dual fuel conversion kit for a gasoline powered engine include :

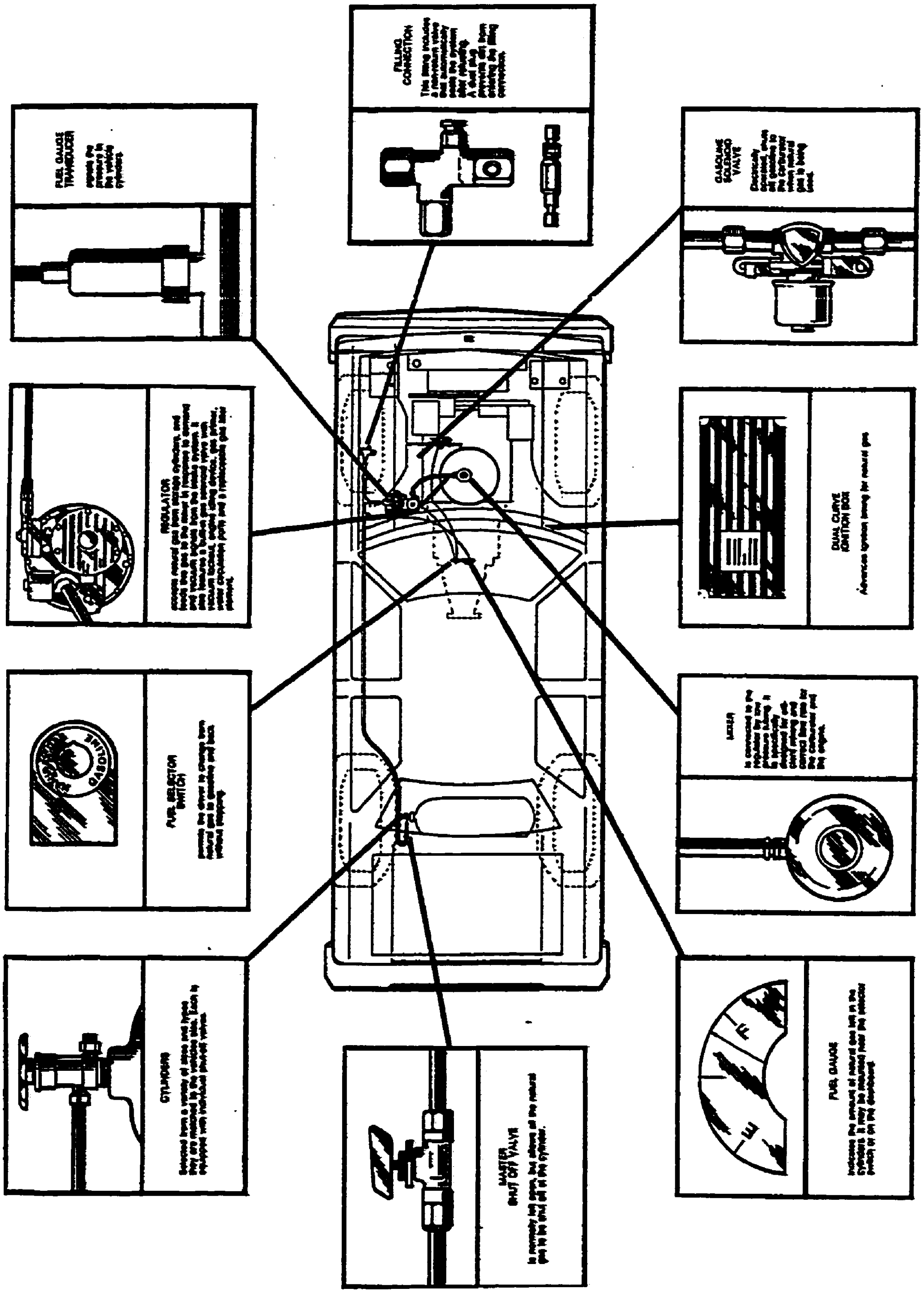
- Natural Gas Storage Cylinders - A compressed natural gas dual fuel conversion consists of the addition of one or more pressure tanks to the vehicle. The number of tanks added to the vehicle depends on the required distances to be traveled between refueling.
- Fuel Selector Switch - Allows the driver to switch between natural gas and gasoline on dual fuel conversions. The switch system includes safety components (gasoline solenoid valve) to assure that gasoline feed is shut off when natural gas is being used.
- Pressure Regulator - The pressure regulator reduces pressure from the storage cylinder(s) and feeds the natural gas to the air-fuel mixer. The pressure regulator also includes a solenoid valve , engine idling device, gas primer and water circulation ports.

- Air-Fuel Mixer - The air-fuel mixer is connected to the pressure regulator and mixes natural gas with combustion and ensures correct flow rate.
- Dual Electronic Ignition - The dual electronic ignition advances the ignition timing to provide an optimal spark curve while using natural gas.
- Filling Connection - The filling connection accepts the re-fueling probe and includes a non-return valve that seals the system after refueling.
- Master Shut Off Valve - The master shut off valve allows the manual shut off of natural gas from the storage cylinder(s).
- Fuel Gage Transducer and Gauge - The fuel gage transducer signals the pressure in the storage cylinders to the fuel gauge. The fuel gauge indicates the quantity of natural gas remaining in the storage cylinder(s).

Since the energy density of natural is much less than gasoline, vehicles require larger storage systems than for gasoline in order to compensate for the lower energy density. In Canada, approved cylinders must have a 3,000 psi (20,690 kPa) rating and must be able to withstand a pressure of 5,000 psi (34,480 kPa). The fuel lines between the fuel tanks and the pressure regulator must be made of approved high-pressure steel tubing and installed so as not to enter the passenger space (Energy Mines and Resources Canada, 1991).

Both normally carbureted and fuel injected gasoline engines can be converted to operate as dual fuel natural gas engines. For school buses with carbureted engines an "open loop" mechanical air-fuel metering and mixing system is used which relies on a venturi and piston type valve. These systems are sensitive to adjustments, temperature, and natural gas

Figure 5: Natural Gas Conversion



Source: Natural Resources Canada

composition. They also can experience difficulty in maintaining the correct air to fuel ratio (Lyons and McCoy, 1993).

More recently, IMPCO, Ortech International and Automotive Natural Gas, Inc. have introduced solid state electronic fuel delivery systems that are designed to be integrated with the original equipment sensor feedback, computer and engine control system (Lyons and McCoy, 1993). The advantage of these systems is that they continuously provide an optimum fuel to air mixture and thereby maximize emission reductions and fuel economy performance across the entire engine speed and load range.

Standards for the fuel system components and installation of a natural gas dual fuel conversion kits are set out by the Standards Council of Canada and the Canadian Standards Association. Standards for fuel system components (not including storage tanks) are published in the Canadian Gas Association document CAN/CGA-12.3-M91 and relevant references. Storage tank standards are published in Canadian Standards Association document B51-M1991 and relevant references. The standards for installation of natural gas conversion kits are published in the Canadian Gas Association document CAN/CGA-B149.4-M91 and relevant references. Manitoba has adopted these documents through legislation as the provincial standards for natural gas conversions. The Manitoba Department of Labour enforces the application of these standards (Weekes, personal communication).

The installed cost of a natural gas conversion for a school bus is may vary between $4,750 and $5,500 and is dependent on the number of storage tanks required (Turner, personal communication).

An important issue for both fleet managers and drivers is the operation of natural gas fueled vehicles as compared to gasoline. The principal issues include vehicle range, performance (power, acceleration and drivability) and maintenance. With regard to vehicle range, the distance the vehicle can travel on a complete fill of natural gas is dependent on the volume of on-board storage capacity, storage pressure and fuel efficiency (Lyons and McCoy, 1993). Natural gas storage capacity should generally be sufficient to operate a full day and allow for overnight refueling.

Vehicle power losses of between 5 and 15 percent can be expected after conversion. Recent technological advances however, have resulted in power losses of 3 to 4 percent. The Translator Conversion System, developed by DAI Controls Division, Synchro-Start Products Inc., is the first dual fuel conversion system designed to work with a vehicle's original diagnostic system (Gas Research Institute, 1996). Using the vehicle's original diagnostic system allows greater precision in adjusting air-fuel mixing and provides greater accuracy in responding to changing demands and conditions.

In a report on the dual fuel conversion of the school buses in the Nipawin School Division (located in Saskatchewan), it was concluded that gasoline was favored over natural gas in terms of performance (Energy, Mines and Resources, 1987). However, newer drivers who were not familiar with typical performance of gasoline fueled engines were positive regarding the driving performance while using natural gas (Energy, Mines and Resource, 1987). In a report on the results of the a dual fuel school bus demonstration project in the Syracuse School District (New York), no driver complaints were registered despite a 13 to 21 percent decline in power output while using natural gas (Mueller Associates, Inc., 1986).

In fact, there are several characteristics of natural gas that offset the reduced engine power. Because natural gas mixes easily with the combustion air as it enters the engine, the air-fuel ratio of each cylinder charge is more uniform. This produces smoother engine operation. Syracuse bus drivers also noted that buses exhibited better "lugging" characteristics when using natural gas (Mueller and Associates Inc., 1986).

Maintenance on school buses converted to operate on natural gas is generally about the same as regular gasoline vehicles (Lyons and McCoy, 1993). Because natural gas is cleaner burning than gasoline it is often suggested that engine oil and spark plug life can be extended. Lyons and McCoy (1993) indicate that school divisions should use caution when considering extending engine oil change intervals. Although the oil remains cleaner and contains lower metal concentration (suggesting reduced engine wear while using natural gas), oil viscosity might decrease This reduces the lubricating protection of the oil.

Engine spark plugs are degraded by gap growth resulting from the energy of the spark, or the build-up of deposits from fuel or oil consumption. As spark plugs degrade, they begin to cause the engine to misfire and therefore reduce fuel efficiency. In the Syracuse demonstration project, spark plug life was extended from 10,000 miles (16,000 kilometres) to 20,000 miles (32,000 kilometres) on natural gas fueled school buses. The greater spark plug life means greater savings from fewer spark plug purchases and labour savings from avoided maintenance.

There is the potential that using natural gas as a vehicle fuel might actually increase maintenance costs to certain vehicle components (Weekes, personal communication). As the addition of natural gas storage tanks to the vehicle increases the weight of the vehicle, increased wear to brakes and suspension components may occur. This would result in increased maintenance expenditures for these components. Furthermore, the installation of a natural gas fuel delivery system in a vehicle result in additional components that must be maintained by school division mechanics. This could further add to maintenance expenses.

The Syracuse demonstration project found no correlation between total vehicle maintenance costs and fuel type. This is primarily because engine maintenance typically only makes up a small portion of the total vehicle maintenance which includes such things as brakes, driveline, wheels, steering and chassis. It is concluded in the review of the Syracuse demonstration project that using natural gas would not significantly affect total school bus maintenance costs (Mueller and Associates Inc., 1986).

APPENDIX B

OTHER SCHOOL BUS FUEL OPTIONS

Apart from natural gas and gasoline, school buses can be fueled with diesel fuel or propane. Methanol and ethanol are other alternative fuels that are could conceivably be used as a vehicle fuel in North America. As decision makers require information about other fuel options, this appendix provides a review of the advantages and disadvantages of these fuels. This review, however, is general in nature and does not provide detailed fleet level economic and emissions analyses.

Diesel Fuel

Many school divisions already have experience with diesel fueled buses. Diesel fueled buses offer several advantages over gasoline buses. These advantages include: reliability and durability of the diesel engine; ease of maintenance; and, fuel cost savings over gasoline. There are two important disadvantages of diesel as compared to gasoline: 1) diesel engines usually produce inadequate interior heat for the passengers, particularly on the highway, as the diesel engines are rarely operated under load in school buses, and; 2) school buses with diesel engines are more expensive than their gasoline engine counterparts.

The emissions from diesel fueled vehicles has primarily focused on the visible smoke and odorous exhaust which are the result of particulate matter and sulfur. Visible smoke is dependent on the engine temperature and whether the engine is being driven under load. Cold engine temperatures at start-up result in 'white smoke' which is comprised of condensed water vapour and unburned diesel fuel and disappears as the engine approaches normal operating temperatures (Owen and Coley, 1990).

'Black smoke' is produced at full engine load as a result of the air-fuel ratio being too rich and is caused by overloading, overfueling or poor maintenance of fuel injectors (Owen and Coley, 1990). 'Black smoke' contains particulates resulting from the incomplete combustion of fuel droplets which produce particles of carbonaceous soot. Other combustion by-products are absorbed in the particulates or condensed onto the surface of the which molecules of other combustion (Owen and Coley, 1990). Particulates can be controlled by trapping them in a filter then combusting them in a catalyst or fuel burner.

Sulfur emissions, which contribute to acid rain, are the result of the presence of sulfur in the diesel fuel and can be controlled by removing the sulfur from the fuel. During the combustion process, sulfur in the diesel fuel form sulfur dioxide (SO_2), sulfur trioxide (SO_3) and solid compound sulfates (Owen and Coley, 1990).

The major advantage of diesel engines is the better fuel economy than gasoline engines due to higher compression ratios, absence of an air-throttle and higher fuel density (Owen and Coley, 1990). Although improvements in gasoline engine fuel economy have closed the gap, lower diesel fuel prices (partly the result of lower government taxation) make diesel fueled vehicles more economical to operate than gasoline fueled vehicles.

The diesel fuel option for school buses is a consideration when school divisions are in the process of replacing aging fleet vehicles. The major attractiveness of the diesel fuel option is the potential fuel cost savings that can be realized as school buses are replaced. The average price of diesel fuel in Winnipeg in 1996 was 7.6 cents per litre less than the price of gasoline (Natural Resources Canada, 1997).

There are several negative aspects of this option when compared to the natural gas option. The natural gas conversion of existing gasoline buses allows savings to be immediately realized rather than waiting for these buses to be replaced. As school divisions only replace a few buses at most each year, the switch-over to diesel fuel would take many years to occur which results in significant foregone savings. As well, using natural gas instead of diesel produces lower tailpipe emissions.

Propane

Propane is used as an automotive fuel in over 140,000 vehicles in Canada as a result of being promoted by government incentive programs in response to rising oil prices and concern for oil security during the late 1970's and 1980's (Heath, 1991). Propane is the main component of liquefied petroleum gas (LPG) which also contains small amounts of other hydrocarbons such as ethane and butane. The automotive grade of propane (HD5) contains no less than 90 percent propane.

As with natural gas, propane is a gas at ambient temperatures and pressures and requires similar modifications to gasoline engines in order to use it as an automotive fuel. The main difference with propane conversions compared to natural gas is that at ambient temperatures, propane requires storage pressures of approximately 175 pounds per square inch (Lyons and McCoy, 1993). At this pressure, propane is a liquid and thus has a higher energy density than natural gas. However, unlike natural gas, under certain extreme climatic conditions, propane fuel delivery systems will not operate (Heath, 1991).

As a result of propane's higher energy density and lower storage pressure, tanks are much lighter and smaller than natural gas storage tanks. The lower pressure of propane also means that fuel delivery lines and pressure regulators are less expensive. Propane pumps for refueling are less expensive and since the fuel does not require as much compression as compared to natural gas.

Propane is available at a number of retail gasoline stations. For propane to be installed at a fleet storage location, a bulk fuel handling facility would have to be installed from which to refuel vehicles. This facility would include a pump, a meter and bulk storage tank which can either be purchased outright or rented from a propane wholesaler (McCall, 1983).

Propane is considered a clean burning fuel as compared to gasoline and produces similar emissions to natural gas (Heath, 1991). Using propane instead of gasoline has the potential for lower reactive hydrocarbons (NMHC), carbon monoxide (CO) and carbon dioxide (CO_2) emissions (Lyons and McCoy, 1993). The Colorado Department of Health undertook a propane emission testing program on six converted vehicles in 1991. The program results included decreased mean emissions of hydrocarbons (12.8%), carbon monoxide (-45.6%), and carbon dioxide (-9.5%). The mean change in emissions of nitrogen oxides increased 1.5%, likely the result of higher combustion chamber temperatures (Lyons and McCoy, 1993).

Similarly to natural gas, exposure to propane does not pose a significant health risk since it is non-toxic. As well, propane is an asphyxiant, which can cause suffocation if sufficient quantity is present (Heath, 1991). There is however one important safety aspect that puts propane at a significant disadvantage to natural gas; propane is more dense than air and therefore leaks from a tank will pool in areas that are not well ventilated, resulting in a serious explosion hazard. Propane fueled vehicles are not permitted to be stored in an underground area because of the explosion hazard (Heath, 1991).

In addition to the safety concerns of propane, an important constraint to using propane as an automotive fuel is its price. The propane is determined by its competitiveness with other chemical feedstocks (ethane, naphtha and gas oil) in the industrial sector and demand as a grain-drying fuel in the agricultural sector (Heath, 1991). These factors create the potential for wide price variations throughout the year. Table 10 illustrates the monthly variations for propane prices in the Winnipeg market during 1996:

Table 10: 1996 Monthly Automotive Propane Prices in Winnipeg*

Month	Cents / Litre	Change (Cents / Litre)	Change Percent
January	37.5	NA	NA
February	38.9	1.4	4%
March	39.0	0.1	0%
April	37.9	-1.1	-3%
May	36.2	-1.7	-4%
June	35.9	-0.3	-1%
July	35.9	0.0	0%
August	32.2	-3.7	-10%
September	24.1	-8.1	-25%
October	27.7	3.6	15%
November	40.6	12.9	47%
December	38.4	-2.2	-5%

*Natural Resources Canada, 1997.

As can be seen from the above table, prices for automotive propane in Winnipeg varied significantly during 1996. Prices ranged from 24.1 cents / litre in September to 40.6 cents per litre in November, a total range of 16.5 cents per litre during the year. Heath (1991) concludes that until automotive propane prices are not affected as significantly by other markets for the product, its competitiveness as an alternative fuel will remain limited.

Although propane is a clean burning alternative fuel to gasoline, the fact that the price fluctuations of propane and its safety concerns results in limited interest in propane conversions for school bus fleets.

Methanol

Methanol can be produced from coal or biomass, however in Canada the principal feedstock for methanol is natural gas (Heath, 1991). It is a clear, colourless, toxic liquid alcohol. Because of its corrosive properties, vehicles using methanol require alternations to metal and elastomer components that come into contact with the fuel. Currently, methanol's major contribution to fuels is in the production of a high octane gasoline additive MTBE.

Methanol is a clean burning, high octane fuel that has only about half the energy content of gasoline but has a 10 to 20 percent better thermal efficiency. These characteristics result in improved vehicle performance of between 5 and 20 percent (Heath, 1991). This increased efficiency however does not fully compensate its lower energy content and thus it requires about 1.7 times the amount of fuel to travel the same distance as gasoline.

Vehicle modifications to operate on methanol include modifications to air/fuel mixing, altering spark timing, installation of a cold start system and reformulated lubricating oils to ensure against methanol corrosion (Heath, 1991). In order to overcome cold starting problems, a small amount of gasoline is added (15 percent) to methanol to produce M85.

Methanol has been shown in testing to provide significantly improved performance and reduced harmful emissions as compared to gasoline fueled vehicles (Heath, 1991). Neat methanol is preferable over M85 because it can take advantage of higher compression ratios, higher heat of vaporization which provides cooling during the compression stroke and higher flame speeds which permits optimal timing and leaner mixtures. M85 however has the important safety advantages of flame visibility and the reduced ignitability of vapors in the fuel tank (Heath, 1991).

Recent transit bus fleet experiments with methanol have produced disappointing results. In 1996 the Los Angeles Metropolitan Transit Agency switched its fleet of 330 alternatively fueled buses from methanol to ethanol (PRNewswire, 1997). The corrosiveness of methanol required bus engines to be rebuilt on average after less than 50,000 miles (83,333 kilometres). Furthermore, up to 20 percent of the methanol fueled buses were out of service at a given time. The Los Angeles Metropolitan Transit Agency is also planning to use more transit buses fueled by natural gas (PRNewswire, 1997).

Methanol does not represent an immediate option for school bus fleets because the fuel is not widely available. Furthermore, the technical problems associated with the corrosiveness of methanol raises serious doubts regarding its technical viability. As the fuel is currently being considered as a long term replacement for gasoline and diesel fuel, a substantial degree of market penetration and technical development for the fuel would be required before it can be seriously considered.

Ethanol

Ethanol is produced from biomass feedstock and is therefore a renewable fuel. Ethanol is currently available in Manitoba from Mohawk Oil as the low-level gasoline blend "gasohol" (a mixture of 90 percent gasoline and 10 percent ethanol). Mohawk produces the ethanol required for the Manitoba (and part of the Alberta and British Columbia markets) at a retrofitted distillery in Minnedosa, Manitoba. Mohawk has been able to develop a strong customer base with environmental based advertising and has received the

"EcoLogo" trademark from the Environmental Choice Program of Environment Canada (Manitoba Energy and Mines, 1995). Using ethanol reduces ozone-forming organic emissions, the major precursor to urban smog. It also results in reductions in hydrocarbons and carbon monoxide emissions but, because of its higher flame temperature, higher nitrogen oxide emissions (Heath, 1991).

Government incentives support both the production and use of gasohol. The federal government provides loan guarantees to support new ethanol facilities and provides an exemption of the excise tax on the ethanol portion of gasohol. The loan guarantee is available beginning in 1999 and is administered by the Farm Credit Corporation (Manitoba Energy and Mines, 1995). The excise tax exemption amounts to 0.85 cent per litre of gasohol sold. The Manitoba government reduces the gasoline tax by 2.5 cents per litre of gasohol sold (Manitoba Energy and Mines, 1995).

Ethanol, as it is an alcohol, is similar to methanol in having a lower vapour pressure and higher heat of vapourization than gasoline. In order to operate vehicles on pure ethanol, similar modifications as methanol fueled vehicles are required. Because ethanol has a higher energy content than methanol, a vehicle operating on E85 (85 percent ethanol/15 percent gasoline) would be able to travel further than a vehicle using M85.

Although ethanol is currently available as a gasoline additive or extender in Manitoba, it is not currently available as a true alternative vehicle fuel. In order for ethanol to become a major transportation fuel, a significant investment in plants and distribution is required

(Heath, 1991). As is the case with methanol, ethanol is not considered to be a viable option for school bus fleets in the short term.

APPENDIX C

SCHOOL DIVISION QUESTIONAIRRE

School Division: Name____________________________________
Address____________________________________

Representative: Name____________________________________
Title____________________________________

1. Number of buses:____________
2. Are buses kept overnight at a central storage location____________
3. Average fuel costs for school year 1995/96:
   gasoline:____________
   diesel fuel:____________
   propane:____________
4. Average age of bus at retirement:____________
5. Criteria determining retirement of buses:________________________
6. Do you prefer gasoline, diesel fuel or propane, and why?____________________
7. When purchasing a new school bus, what is your buying decision based on, in order of importance:
   capital cost____________
   expected life_
   operating costs____________
   warranty____________
   fuel economy____________
   environment ____________
8. What is your perception of natural gas as a vehicle fuel?____________________

Bus	Year	Fuel Type	Seating Capacity	Daily Route (Kilometres)	Yearly (Kilometres)	Annual Fuel Consumption
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						
16.						
17.						
18.						
19.						
20.						
21.						
22.						
23.						
24.						
25.						
26.						
27.						
28.						
29.						
30.						

Bus	Year	Fuel Type	Seating Capacity	Daily Route (Kilometres)	Yearly (Kilometres)	Annual Fuel Consumption
31.						
32.						
33.						
34.						
35.						
36.						
37.						
38.						
39.						
40.						
41.						
42.						
43.						
44.						
45.						
46.						
47.						
48.						
49.						
50.						
51.						
52.						
53.						
54.						
55.						
56.						
57.						
58.						
59.						
60.						

APPENDIX D

ENERGY CONVERSIONS

Natural Gas:	
Density	0.693 kilograms/cubic metre
Lower Heating Value	33.17 megajoules/cubic metre
Gasoline:	
Lower Heating Value	32.40 megajoules/cubic metre
Diesel Fuel:	
Lower Heating Value	36.40 megajoules/cubic metre

Source: Sypher:Mueller, 1991

APPENDIX E

SCHOOL DIVISION SPREADSHEETS

NGV SCHOOL BUS CONVERSION SUMMARY

SCHOOL DIVISION DATA	
School Division	Assiniboine South
No.:	3

VEHICLE DATA	
Number of Conversion Fleet Buses	14
Convs. Fleet Gasoline Displacement (litres)	88,766
Convs. Fleet Natural Gas Consumption (m3	85,247
Convs. Fleet Annual Distance (kilometres)	129,690

ASSUMPTIONS	
Fuel Prices	
Natural Gas Price ($/m3)	$0.880
Natural Gas Price Equivalent ($/litre eq.)	$0.118
Gasoline Price ($/litre)	$0.505
Fuel Price Difference	$0.387
Conversion Costs	
Conversion Kit	($2,500.00)
Tanks	($3,000.00)
Labour	Included
Total (plus GST & PST)	($6,008.20)
Operating Cost	
Station Maintenance ($/L eq.)	($0.04)
Power ($/L eq.)	($0.01)
Total	($0.05)
Training Expense	($750.00)
Discount Rate	5.00%
Analysis Period (Years)	13

EMISSIONS REDUCTIONS (Kilograms)	
Total Hydrocarbons (kg)	-859
Non-Methane Hydrocarbons (kg)	72
Carbon Monoxide (kg)	7,003
Nitrogen Oxides (kg)	285
Carbon Dioxide (kg)	132,174

ECONOMIC ANALYSIS RESULTS	NPV	ANNUALIZED
COSTS		
CONVERSION COSTS		
Total Conversion Cost	($84,114.80)	
Amortized Conversion Cost		($8,954.51)
REFUELING FACILITY		
Capital Cost	($228,410.31)	
Amortized Refueling Facility		($26,165.76)
TRAINING EXPENSES	($750.00)	
Amortized Training Expenses		($79.84)
OPERATING EXPENSES	($41,274.63)	
Total Annual Operating Expenses		($4,393.92)
TOTAL COSTS		
Total Capital and Training Costs	($313,275.11)	
Present Value Operating Costs	($41,274.63)	
Present Value of Costs	($354,549.74)	
Total Annual Amortization and Operating Expenses Cash Flow		($39,594.03)
SAVINGS		
FUEL EXPENSE SAVINGS		
Present Value of Savings	$281,815.68	
Annual Fuel Savings		$30,000.90
RESULTS		
Net Present Value	($72,734.06)	
Net Financial Annual Savings		($9,593.13)

SENSITIVITIES (To Result In Net Present Value = $0.00)		
Factor	Value	Change
Natural Gas Price Equivalent ($/litre ec	$0.03	-75%
Gasoline Price ($/litre)	$0.60	19%
Conversion Cost Per Unit	$812.91	-86%
Refueling Facilities	$167,522.00	-27%
Discount Rate	1.36%	73%

Economic Analysis of NGV Conversion
School Division Assiniboine South

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Salvage
COSTS															
CONVERSION COSTS															
No. of Bus Conversions	14														
Cost per Conversion	($6,008)														
Total Conversion Cost	($84,115)														
Amortized Conversion Cost		($8,956)	($8,956)	($8,956)	($8,956)	($8,956)	($8,956)	($8,956)	($8,956)	($8,956)	($8,956)	($8,956)	($8,956)	($8,956)	$0
REFUELING FACILITY															
Natural Gas Consumption (l eq.)	87,878														
Capital Cost	($245,790)														
Amortized Refueling Facility		($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	$32,772
Present Value of Salvage	$17,380														
TRAINING EXPENSES	($750)														
Amortized Training Expenses		($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	
OPERATING EXPENSES															
Natural Gas Cons. (gasoline l. eq.)		87,878	87,878	87,878	87,878	87,878	87,878	87,878	87,878	87,878	87,878	87,878	87,878	87,878	
Station Maintenance		($3,515)	($3,515)	($3,515)	($3,515)	($3,515)	($3,515)	($3,515)	($3,515)	($3,515)	($3,515)	($3,515)	($3,515)	($3,515)	
Power		($879)	($879)	($879)	($879)	($879)	($879)	($879)	($879)	($879)	($879)	($879)	($879)	($879)	
Total Annual Operating Expenses		($4,394)	($4,394)	($4,394)	($4,394)	($4,394)	($4,394)	($4,394)	($4,394)	($4,394)	($4,394)	($4,394)	($4,394)	($4,394)	
TOTAL COSTS															
Total Capital and Training Costs	($313,275)														
Present Value Operating Costs	($41,275)														
Present Value of Costs	($354,550)														
Total Annualized Costs and Operating Expenses		($39,594)	($39,594)	($39,594)	($39,594)	($39,594)	($39,594)	($39,594)	($39,594)	($39,594)	($39,594)	($39,594)	($39,594)	($39,594)	
SAVINGS															
FUEL EXPENSE SAVINGS AFTER CONVERSION															
Natural Gas Consumption (m^3)		85,247	85,247	85,247	85,247	85,247	85,247	85,247	85,247	85,247	85,247	85,247	85,247	85,247	
Gasoline Consumption		8,877	8,877	8,877	8,877	8,877	8,877	8,877	8,877	8,877	8,877	8,877	8,877	8,877	
Total Fuel Savings Cash Flow		$30,001	$30,001	$30,001	$30,001	$30,001	$30,001	$30,001	$30,001	$30,001	$30,001	$30,001	$30,001	$30,001	
Present Value of Savings	$281,816														
PRESENT VALUE AND NET ANNUALIZED SAVINGS															
Net Present Value	($72,734)														
Net Annualized Savings		($9,593)	($9,593)	($9,593)	($9,593)	($9,593)	($9,593)	($9,593)	($9,593)	($9,593)	($9,593)	($9,593)	($9,593)	($9,593)	

Emissions Analysis of NGV Conversion
School Division Assiniboine South

Category	Totals	Year												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Total Conversion Kilometres	1,685,970	129,690	129,690	129,690	129,690	129,690	129,690	129,690	129,690	129,690	129,690	129,690	129,690	129,690
Total Hydrocarbons (kg)	-859	-66.09	-66.09	-66.09	-66.09	-66.09	-66.09	-66.09	-66.09	-66.09	-66.09	-66.09	-66.09	-66.09
Non-Methane Hydrocarbons (kg)	72	5.58	5.58	5.58	5.58	5.58	5.58	5.58	5.58	5.58	5.58	5.58	5.58	5.58
Carbon Monoxide (kg)	7,003	538.67	538.67	538.67	538.67	538.67	538.67	538.67	538.67	538.67	538.67	538.67	538.67	538.67
Nitrogen Oxides (kg)	285	21.92	21.92	21.92	21.92	21.92	21.92	21.92	21.92	21.92	21.92	21.92	21.92	21.92
Carbon Dioxide (kg)	132,174	10,167.24	10,167.24	10,167.24	10,167.24	10,167.24	10,167.24	10,167.24	10,167.24	10,167.24	10,167.24	10,167.24	10,167.24	10,167.24

NGV SCHOOL BUS CONVERSION SUMMARY

SCHOOL DIVISION DATA	
School Division	Brandon
No.:	12

VEHICLE DATA	
Number of Conversion Fleet Buses	33
Convs. Fleet Gasoline Displacement (litres)	369,588
Convs. Fleet Natural Gas Consumption (m3	354,937
Convs. Fleet Annual Distance (kilometres)	608,419

ASSUMPTIONS	
Fuel Prices	
Natural Gas Price ($/m3)	$0.880
Natural Gas Price Equivalent ($/litre eq.)	$0.118
Gasoline Price ($/litre)	$0.450
Fuel Price Difference	$0.332
Conversion Costs	
Conversion Kit	($2,500.00)
Tanks	($3,000.00)
Labour	Included
Total (plus GST & PST)	($6,008.20)
Operating Cost	
Station Maintenance ($/L eq.)	($0.04)
Power ($/L eq.)	($0.01)
Total	($0.05)
Training Expense	($750.00)
Discount Rate	5.00%
Analysis Period (Years)	13

EMISSIONS REDUCTIONS (Kilograms)	
Total Hydrocarbons (kg)	-4,031
Non-Methane Hydrocarbons (kg)	340
Carbon Monoxide (kg)	32,852
Nitrogen Oxides (kg)	1,337
Carbon Dioxide (kg)	620,073

ECONOMIC ANALYSIS RESULTS	NPV	ANNUALIZED
COSTS		
CONVERSION COSTS		
Total Conversion Cost	($198,270.60)	
Amortized Conversion Cost		($21,107.05)
REFUELING FACILITY		
Capital Cost (including Salvage)	($304,547.08)	
Amortized Refueling Facility		($34,887.68)
TRAINING EXPENSES	($750.00)	
Amortized Training Expenses		($79.84)
OPERATING EXPENSES	($171,851.77)	
Total Annual Operating Expenses		($18,294.61)
TOTAL COSTS		
Total Capital and Training Costs	($503,567.68)	
Present Value Operating Costs	($171,851.77)	
Present Value of Costs	($675,419.45)	
Total Annual Amortization and Operating Expenses Cash Flow		($74,369.19)
SAVINGS		
FUEL EXPENSE SAVINGS		
Present Value of Savings	$1,001,520.88	
Annual Fuel Savings		$106,617.67
RESULTS		
Net Present Value	$326,101.43	
Net Financial Annual Savings		$32,248.49

SENSITIVITIES (To Result in Net Present Value = $0.00)		
Factor	Value	Change
Natural Gas Price Equivalent ($/litre eq	$0.21	81%
Gasoline Price ($/litre)	$0.35	-23%
Conversion Cost Per Unit	$15,890.00	164%
Refueling Facilities	$678,634.00	123%
Discount Rate	13.89%	178%

Economic Analysis of NGV Conversion
School Division Brandon

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Salvage
COSTS															
CONVERSION COSTS															
No. of Bus Conversions	33														
Cost per Conversion	($6,008)														
Total Conversion Cost	($198,271)														
Amortized Conversion Cost		($21,107)	($21,107)	($21,107)	($21,107)	($21,107)	($21,107)	($21,107)	($21,107)	($21,107)	($21,107)	($21,107)	($21,107)	($21,107)	$0
REFUELING FACILITY															
Natural Gas Consumption (l eq.)	365,892														
Capital Cost	($327,720)														
Amortized Refueling Facility		($34,888)	($34,888)	($34,888)	($34,888)	($34,888)	($34,888)	($34,888)	($34,888)	($34,888)	($34,888)	($34,888)	($34,888)	($34,888)	$43,696
Present Value of Salvage	$23,173														
TRAINING EXPENSES	($750)														
Amortized Training Expenses		($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	
OPERATING EXPENSES															
Natural Gas Cons. (gasoline l. eq.)		365,892	365,892	365,892	365,892	365,892	365,892	365,892	365,892	365,892	365,892	365,892	365,892	365,892	
Station Maintenance		($14,636)	($14,636)	($14,636)	($14,636)	($14,636)	($14,636)	($14,636)	($14,636)	($14,636)	($14,636)	($14,636)	($14,636)	($14,636)	
Power		($3,659)	($3,659)	($3,659)	($3,659)	($3,659)	($3,659)	($3,659)	($3,659)	($3,659)	($3,659)	($3,659)	($3,659)	($3,659)	
Total Annual Operating Expenses		($18,295)	($18,295)	($18,295)	($18,295)	($18,295)	($18,295)	($18,295)	($18,295)	($18,295)	($18,295)	($18,295)	($18,295)	($18,295)	
TOTAL COSTS															
Total Capital and Training Costs	($503,568)														
Present Value Operating Costs	($171,852)														
Present Value of Costs	($675,419)														
Total Annualized Costs and Operating Expenses		($74,369)	($74,369)	($74,369)	($74,369)	($74,369)	($74,369)	($74,369)	($74,369)	($74,369)	($74,369)	($74,369)	($74,369)	($74,369)	
SAVINGS															
FUEL EXPENSE SAVINGS AFTER CONVERSION															
Natural Gas Consumption (m^3)		354,937	354,937	354,937	354,937	354,937	354,937	354,937	354,937	354,937	354,937	354,937	354,937	354,937	
Gasoline Consumption		36,959	36,959	36,959	36,959	36,959	36,959	36,959	36,959	36,959	36,959	36,959	36,959	36,959	
Total Fuel Savings Cash Flow		$106,618	$106,618	$106,618	$106,618	$106,618	$106,618	$106,618	$106,618	$106,618	$106,618	$106,618	$106,618	$106,618	
Present Value of Savings	$1,001,521														
PRESENT VALUE AND NET ANNUALIZED SAVINGS															
Net Present Value	$326,101														
Net Annualized Savings		$32,248	$32,248	$32,248	$32,248	$32,248	$32,248	$32,248	$32,248	$32,248	$32,248	$32,248	$32,248	$32,248	

Emissions Analysis of NGV Conversion
School Division Brandon

Category	Totals	Year												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Total Conversion Kilometres	7,909,446	608,419	608,419	608,419	608,419	608,419	608,419	608,419	608,419	608,419	608,419	608,419	608,419	608,419
Total Hydrocarbons (kg)	-4,031	-310.07	-310.07	-310.07	-310.07	-310.07	-310.07	-310.07	-310.07	-310.07	-310.07	-310.07	-310.07	-310.07
Non-Methane Hydrocarbons (kg)	340	26.16	26.16	26.16	26.16	26.16	26.16	26.16	26.16	26.16	26.16	26.16	26.16	26.16
Carbon Monoxide (kg)	32,852	2,527.07	2,527.07	2,527.07	2,527.07	2,527.07	2,527.07	2,527.07	2,527.07	2,527.07	2,527.07	2,527.07	2,527.07	2,527.07
Nitrogen Oxides (kg)	1,337	102.85	102.85	102.85	102.85	102.85	102.85	102.85	102.85	102.85	102.85	102.85	102.85	102.85
Carbon Dioxide (kg)	620,073	47,697.92	47,697.92	47,697.92	47,697.92	47,697.92	47,697.92	47,697.92	47,697.92	47,697.92	47,697.92	47,697.92	47,697.92	47,697.92

NGV SCHOOL BUS CONVERSION SUMMARY

SCHOOL DIVISION DATA	
School Division	Fort Garry School
No.:	5

VEHICLE DATA	
Number of Conversion Fleet Buses	18
Convs. Fleet Gasoline Displacement (litres)	136,000
Convs. Fleet Natural Gas Consumption (m3	130,609
Convs. Fleet Annual Distance (kilometres)	251,681

ASSUMPTIONS	
Fuel Prices	
Natural Gas Price ($/m3)	$0.880
Natural Gas Price Equivalent ($/litre eq.)	$0.118
Gasoline Price ($/litre)	$0.500
Fuel Price Difference	$0.382
Conversion Costs	
Conversion Kit	($2,500.00)
Tanks	($3,000.00)
Labour	Included
Total (plus GST & PST)	($6,008.20)
Operating Cost	
Station Maintenance ($/L eq.)	($0.04)
Power ($/L eq.)	($0.01)
Total	($0.05)
Training Expense	($750.00)
Discount Rate	5.00%
Analysis Period (Years)	13

EMISSIONS REDUCTIONS (Kilograms)	
Total Hydrocarbons (kg)	-1,667
Non-Methane Hydrocarbons (kg)	141
Carbon Monoxide (kg)	13,590
Nitrogen Oxides (kg)	553
Carbon Dioxide (kg)	256,502

ECONOMIC ANALYSIS RESULTS	NPV	ANNUALIZED
COSTS		
CONVERSION COSTS		
Total Conversion Cost	($108,147.60)	
Amortized Conversion Cost		($11,512.94)
REFUELING FACILITY		
Capital Cost (Including Salvage)	($228,410.31)	
Amortized Refueling Facility		($26,165.76)
TRAINING EXPENSES	($750.00)	
Amortized Training Expenses		($79.84)
OPERATING EXPENSES	($63,237.53)	
Total Annual Operating Expenses		($6,732.00)
TOTAL COSTS		
Total Capital and Training Costs	($337,307.91)	
Present Value Operating Costs	($63,237.53)	
Present Value of Costs	($400,545.44)	
Total Annual Amortization and Operating Expenses Cash Flow		($44,490.54)
SAVINGS		
FUEL EXPENSE SAVINGS		
Present Value of Savings	$426,025.51	
Annual Fuel Savings		$45,352.87
RESULTS		
Net Present Value	$25,480.07	
Net Financial Annual Savings		$862.33

SENSITIVITIES (To Result in Net Present Value = $0.00)		
Factor	Value	Change
Natural Gas Price Equivalent ($/litre e	$0.14	17%
Gasoline Price ($/litre)	$0.48	-4%
Conversion Cost Per Unit	$7,423.76	24%
Refueling Facilities	$273,209.00	20%
Discount Rate	6.12%	22%

Economic Analysis of NGV Conversion
School Division Fort Garry School

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Salvage
COSTS															
CONVERSION COSTS															
No. of Bus Conversions	18														
Cost per Conversion	($6,008)														
Total Conversion Cost	($108,148)														
Amortized Conversion Cost		($11,513)	($11,513)	($11,513)	($11,513)	($11,513)	($11,513)	($11,513)	($11,513)	($11,513)	($11,513)	($11,513)	($11,513)	($11,513)	$0
REFUELING FACILITY															
Natural Gas Consumption (l eq.)	134,640														
Capital Cost	($245,790)														
Amortized Refueling Facility		($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	$32,772
Present Value of Salvage	$17,380														
TRAINING EXPENSES	($760)														
Amortized Training Expenses		($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	
OPERATING EXPENSES															
Natural Gas Cons. (gasoline l eq.)		134,640	134,640	134,640	134,640	134,640	134,640	134,640	134,640	134,640	134,640	134,640	134,640	134,640	
Station Maintenance		($5,386)	($5,386)	($5,386)	($5,386)	($5,386)	($5,386)	($5,386)	($5,386)	($5,386)	($5,386)	($5,386)	($5,386)	($5,386)	
Power		($1,346)	($1,346)	($1,346)	($1,346)	($1,346)	($1,346)	($1,346)	($1,346)	($1,346)	($1,346)	($1,346)	($1,346)	($1,346)	
Total Annual Operating Expenses		($6,732)	($6,732)	($6,732)	($6,732)	($6,732)	($6,732)	($6,732)	($6,732)	($6,732)	($6,732)	($6,732)	($6,732)	($6,732)	
TOTAL COSTS															
Total Capital and Training Costs	($337,309)														
Present Value Operating Costs	($63,238)														
Present Value of Costs	($400,545)														
Total Annualized Costs and Operating Expenses		($44,491)	($44,491)	($44,491)	($44,491)	($44,491)	($44,491)	($44,491)	($44,491)	($44,491)	($44,491)	($44,491)	($44,491)	($44,491)	
SAVINGS															
FUEL EXPENSE SAVINGS AFTER CONVERSION															
Natural Gas Consumption (m^3)		130,609	130,609	130,609	130,609	130,609	130,609	130,609	130,609	130,609	130,609	130,609	130,609	130,609	
Gasoline Consumption		13,600	13,600	13,600	13,600	13,600	13,600	13,600	13,600	13,600	13,600	13,600	13,600	13,600	
Total Fuel Savings Cash Flow		$45,353	$45,353	$45,353	$45,353	$45,353	$45,353	$45,353	$45,353	$45,353	$45,353	$45,353	$45,353	$45,353	
Present Value of Savings	$426,026														
PRESENT VALUE AND NET ANNUALIZED SAVINGS															
Net Present Value	$25,480														
Net Annualized Savings		$862	$862	$862	$862	$862	$862	$862	$862	$862	$862	$862	$862	$862	

Emissions Analysis of NGV Conversion
School Division Fort Garry School

Category	Totals	Year												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Total Conversion Kilometres	3,271,858	251,681	251,681	251,681	251,681	251,681	251,681	251,681	251,681	251,681	251,681	251,681	251,681	251,681
Total Hydrocarbons (kg)	-1,667	-128.27	-128.27	-128.27	-128.27	-128.27	-128.27	-128.27	-128.27	-128.27	-128.27	-128.27	-128.27	-128.27
Non-Methane Hydrocarbons (kg)	141	10.82	10.82	10.82	10.82	10.82	10.82	10.82	10.82	10.82	10.82	10.82	10.82	10.82
Carbon Monoxide (kg)	13,590	1,045.36	1,045.36	1,045.36	1,045.36	1,045.36	1,045.36	1,045.36	1,045.36	1,045.36	1,045.36	1,045.36	1,045.36	1,045.36
Nitrogen Oxides (kg)	553	42.55	42.55	42.55	42.55	42.55	42.55	42.55	42.55	42.55	42.55	42.55	42.55	42.55
Carbon Dioxide (kg)	256,502	19,730.95	19,730.95	19,730.95	19,730.95	19,730.95	19,730.95	19,730.95	19,730.95	19,730.95	19,730.95	19,730.95	19,730.95	19,730.95

NGV SCHOOL BUS CONVERSION SUMMARY

SCHOOL DIVISION DATA	
School Division	Garden Valley
No.:	26

VEHICLE DATA	
Number of Conversion Fleet Buses	12
Convs. Fleet Gasoline Displacement (litres)	97,268
Convs. Fleet Natural Gas Consumption (m3	93,412
Convs. Fleet Annual Distance (kilometres)	163,102

ASSUMPTIONS	
Fuel Prices	
Natural Gas Price ($/m3)	$0.880
Natural Gas Price Equivalent ($/litre eq.)	$0.118
Gasoline Price ($/litre)	$0.482
Fuel Price Difference	$0.364
Conversion Costs	
Conversion Kit	($2,500.00)
Tanks	($3,000.00)
Labour	Included
Total (plus GST & PST)	($6,008.20)
Operating Cost	
Station Maintenance ($/L eq.)	($0.04)
Power ($/L eq.)	($0.01)
Total	($0.05)
Training Expense	($750.00)
Discount Rate	5.00%
Analysis Period (Years)	13

EMISSIONS REDUCTIONS (Kilograms)	
Total Hydrocarbons (kg)	-1,081
Non-Methane Hydrocarbons (kg)	91
Carbon Monoxide (kg)	8,807
Nitrogen Oxides (kg)	358
Carbon Dioxide (kg)	166,226

ECONOMIC ANALYSIS RESULTS	NPV	ANNUALIZED
COSTS		
CONVERSION COSTS		
Total Conversion Cost	($72,098.40)	
Amortized Conversion Cost		($7,675.29)
REFUELING FACILITY		
Capital Cost (Including Salvage)	($228,410.31)	
Amortized Refueling Facility		($26,165.76)
TRAINING EXPENSES	($750.00)	
Amortized Training Expenses		($79.84)
OPERATING EXPENSES	($45,227.86)	
Total Annual Operating Expenses		($4,814.77)
TOTAL COSTS		
Total Capital and Training Costs	($301,258.71)	
Present Value Operating Costs	($45,227.86)	
Present Value of Costs	($346,486.56)	
Total Annual Amortization and Operating Expenses Cash Flow		($38,735.66)
SAVINGS		
FUEL EXPENSE SAVINGS		
Present Value of Savings	$289,729.64	
Annual Fuel Savings		$30,843.39
RESULTS		
Net Present Value	($56,756.92)	
Net Financial Annual Savings		($7,892.27)

SENSITIVITIES (To Result in Net Present Value = $0.00)		
Factor	Value	Change
Natural Gas Price Equivalent ($/litre e	$0.06	-53%
Gasoline Price ($/litre)	$0.55	14%
Conversion Cost Per Unit	$1,278.46	-79%
Refueling Facilities	$184,714.00	-19%
Discount Rate	2.09%	-58%

Economic Analysis of NGV Conversion
School Division Garden Valley

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Salvage
COSTS															
CONVERSION COSTS															
No. of Bus Conversions	12														
Cost per Conversion	($6,008)														
Total Conversion Cost	($72,098)														
Amortized Conversion Cost		($7,675)	($7,675)	($7,675)	($7,675)	($7,675)	($7,675)	($7,675)	($7,675)	($7,675)	($7,675)	($7,675)	($7,675)	($7,675)	$0
REFUELING FACILITY															
Natural Gas Consumption (l eq.)	96,295														
Capital Cost	($245,790)														
Amortized Refueling Facility		($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	$32,772
Present Value of Salvage	$17,380														
TRAINING EXPENSES	($750)														
Amortized Training Expenses		($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	
OPERATING EXPENSES															
Natural Gas Cons. (gasoline l. eq.)		96,295	96,295	96,295	96,295	96,295	96,295	96,295	96,295	96,295	96,295	96,295	96,295	96,295	
Station Maintenance		($3,852)	($3,852)	($3,852)	($3,852)	($3,852)	($3,852)	($3,852)	($3,852)	($3,852)	($3,852)	($3,852)	($3,852)	($3,852)	
Power		($963)	($963)	($963)	($963)	($963)	($963)	($963)	($963)	($963)	($963)	($963)	($963)	($963)	
Total Annual Operating Expenses		($4,815)	($4,815)	($4,815)	($4,815)	($4,815)	($4,815)	($4,815)	($4,815)	($4,815)	($4,815)	($4,815)	($4,815)	($4,815)	
TOTAL COSTS															
Total Capital and Training Costs	($301,259)														
Present Value Operating Costs	($45,228)														
Present Value of Costs	($346,487)														
Total Annualized Costs and Operating Expenses		($38,736)	($38,736)	($38,736)	($38,736)	($38,736)	($38,736)	($38,736)	($38,736)	($38,736)	($38,736)	($38,736)	($38,736)	($38,736)	
SAVINGS															
FUEL EXPENSE SAVINGS AFTER CONVERSION															
Natural Gas Consumption (m³)		93,412	93,412	93,412	93,412	93,412	93,412	93,412	93,412	93,412	93,412	93,412	93,412	93,412	
Gasoline Consumption		9,727	9,727	9,727	9,727	9,727	9,727	9,727	9,727	9,727	9,727	9,727	9,727	9,727	
Total Fuel Savings Cash Flow		$30,843	$30,843	$30,843	$30,843	$30,843	$30,843	$30,843	$30,843	$30,843	$30,843	$30,843	$30,843	$30,843	
Present Value of Savings	$289,730														
PRESENT VALUE AND NET ANNUALIZED SAVINGS															
Net Present Value	($56,757)														
Net Annualized Savings		($7,892)	($7,892)	($7,892)	($7,892)	($7,892)	($7,892)	($7,892)	($7,892)	($7,892)	($7,892)	($7,892)	($7,892)	($7,892)	

Emissions Analysis of NGV Conversion
School Division Garden Valley

Category	Totals	Year												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Total Conversion Kilometres	2,120,321	163,102	163,102	163,102	163,102	163,102	163,102	163,102	163,102	163,102	163,102	163,102	163,102	163,102
Total Hydrocarbons (kg)	-1,081	-83.12	-83.12	-83.12	-83.12	-83.12	-83.12	-83.12	-83.12	-83.12	-83.12	-83.12	-83.12	-83.12
Non-Methane Hydrocarbons (kg)	91	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01	7.01
Carbon Monoxide (kg)	8,807	677.44	677.44	677.44	677.44	677.44	677.44	677.44	677.44	677.44	677.44	677.44	677.44	677.44
Nitrogen Oxides (kg)	358	27.57	27.57	27.57	27.57	27.57	27.57	27.57	27.57	27.57	27.57	27.57	27.57	27.57
Carbon Dioxide (kg)	166,226	12,786.60	12,786.60	12,786.60	12,786.60	12,786.60	12,786.60	12,786.60	12,786.60	12,786.60	12,786.60	12,786.60	12,786.60	12,786.60

NGV SCHOOL BUS CONVERSION SUMMARY

SCHOOL DIVISION DATA	
School Division	Morris - MacDonald
No.:	19

VEHICLE DATA	
Number of Conversion Fleet Buses	22
Convs. Fleet Gasoline Displacement (litres)	222,541
Convs. Fleet Natural Gas Consumption (m3	213,719
Convs. Fleet Annual Distance (kilometres)	509,580

ASSUMPTIONS	
Fuel Prices	
Natural Gas Price ($/m3)	$0.880
Natural Gas Price Equivalent ($/litre eq.)	$0.118
Gasoline Price ($/litre)	$0.549
Fuel Price Difference	$0.431
Conversion Costs	
Conversion Kit	($2,500.00)
Tanks	($3,000.00)
Labour	Included
Total (plus GST & PST)	($6,008.20)
Operating Cost	
Station Maintenance ($/L eq.)	($0.04)
Power ($/L eq.)	($0.01)
Total	($0.05)
Training Expense	($750.00)
Discount Rate	5.00%
Analysis Period (Years)	13

EMISSIONS REDUCTIONS (Kilograms)	
Total Hydrocarbons (kg)	-3,376
Non-Methane Hydrocarbons (kg)	285
Carbon Monoxide (kg)	27,515
Nitrogen Oxides (kg)	1,120
Carbon Dioxide (kg)	519,341

ECONOMIC ANALYSIS RESULTS	NPV	ANNUALIZED
COSTS		
CONVERSION COSTS		
Total Conversion Cost	($132,180.40)	
Amortized Conversion Cost		($14,071.37)
REFUELING FACILITY		
Capital Cost (Including Salvage)	($228,410.31)	
Amortized Refueling Facility		($26,165.76)
TRAINING EXPENSES	($750.00)	
Amortized Training Expenses		($79.84)
OPERATING EXPENSES	($103,477.59)	
Total Annual Operating Expenses		($11,015.79)
TOTAL COSTS		
Total Capital and Training Costs	($361,340.71)	
Present Value Operating Costs	($103,477.59)	
Present Value of Costs	($464,818.30)	
Total Annual Amortization and Operating Expenses Cash Flow		($51,332.76)
SAVINGS		
FUEL EXPENSE SAVINGS		
Present Value of Savings	$789,308.27	
Annual Fuel Savings		$84,026.42
RESULTS		
Net Present Value	$324,489.96	
Net Financial Annual Savings		$32,693.66

SENSITIVITIES (To Result In Net Present Value = $0.00)		
Factor	**Value**	**Change**
Natural Gas Price Equivalent ($/litre ec	$0.27	133%
Gasoline Price ($/litre)	$0.38	-31%
Conversion Cost Per Unit	$20,757.74	245%
Refueling Facilities	$594,970.00	160%
Discount Rate	16.95%	239%

Economic Analysis of NGV Conversion
School Division Morris - MacDonald

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Salvage
COSTS															
CONVERSION COSTS															
No. of Bus Conversions	22														
Cost per Conversion	($6,008)														
Total Conversion Cost	($132,180)														
Amortized Conversion Cost		($14,071)	($14,071)	($14,071)	($14,071)	($14,071)	($14,071)	($14,071)	($14,071)	($14,071)	($14,071)	($14,071)	($14,071)	($14,071)	$0
REFUELING FACILITY															
Natural Gas Consumption (l eq.)	220,316														
Capital Cost	($245,790)														
Amortized Refueling Facility		($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	$32,772
Present Value of Salvage	$17,380														
TRAINING EXPENSES	($750)														
Amortized Training Expenses		($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	
OPERATING EXPENSES															
Natural Gas Cons. (gasoline l. eq.)		220,316	220,316	220,316	220,316	220,316	220,316	220,316	220,316	220,316	220,316	220,316	220,316	220,316	
Station Maintenance		($8,813)	($8,813)	($8,813)	($8,813)	($8,813)	($8,813)	($8,813)	($8,813)	($8,813)	($8,813)	($8,813)	($8,813)	($8,813)	
Power		($2,203)	($2,203)	($2,203)	($2,203)	($2,203)	($2,203)	($2,203)	($2,203)	($2,203)	($2,203)	($2,203)	($2,203)	($2,203)	
Total Annual Operating Expenses		($11,016)	($11,016)	($11,016)	($11,016)	($11,016)	($11,016)	($11,016)	($11,016)	($11,016)	($11,016)	($11,016)	($11,016)	($11,016)	
TOTAL COSTS															
Total Capital and Training Costs	($381,341)														
Present Value Operating Costs	($103,478)														
Present Value of Costs	($464,818)														
Total Annualized Costs and Operating Expenses		($51,333)	($51,333)	($51,333)	($51,333)	($51,333)	($51,333)	($51,333)	($51,333)	($51,333)	($51,333)	($51,333)	($51,333)	($51,333)	
SAVINGS															
FUEL EXPENSE SAVINGS AFTER CONVERSION															
Natural Gas Consumption (m^3)		213,719	213,719	213,719	213,719	213,719	213,719	213,719	213,719	213,719	213,719	213,719	213,719	213,719	
Gasoline Consumption		22,254	22,254	22,254	22,254	22,254	22,254	22,254	22,254	22,254	22,254	22,254	22,254	22,254	
Total Fuel Savings Cash Flow		$84,026	$84,026	$84,026	$84,026	$84,026	$84,026	$84,026	$84,026	$84,026	$84,026	$84,026	$84,026	$84,026	
Present Value of Savings	$789,308														
PRESENT VALUE AND NET ANNUALIZED SAVINGS															
Net Present Value	$324,490														
Net Annualized Savings		$32,694	$32,694	$32,694	$32,694	$32,694	$32,694	$32,694	$32,694	$32,694	$32,694	$32,694	$32,694	$32,694	

Emissions Analysis of NGV Conversion
School Division Morris - MacDonald

Category	Totals	Year												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Total Conversion Kilometres	6,624,540	509,580	509,580	509,580	509,580	509,580	509,580	509,580	509,580	509,580	509,580	509,580	509,580	509,580
Total Hydrocarbons (kg)	-3,376	-259.70	-259.70	-259.70	-259.70	-259.70	-259.70	-259.70	-259.70	-259.70	-259.70	-259.70	-259.70	-259.70
Non-Methane Hydrocarbons (kg)	285	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91	21.91
Carbon Monoxide (kg)	27,515	2,116.55	2,116.55	2,116.55	2,116.55	2,116.55	2,116.55	2,116.55	2,116.55	2,116.55	2,116.55	2,116.55	2,116.55	2,116.55
Nitrogen Oxides (kg)	1,120	86.14	86.14	86.14	86.14	86.14	86.14	86.14	86.14	86.14	86.14	86.14	86.14	86.14
Carbon Dioxide (kg)	519,341	39,949.30	39,949.30	39,949.30	39,949.30	39,949.30	39,949.30	39,949.30	39,949.30	39,949.30	39,949.30	39,949.30	39,949.30	39,949.30

NGV SCHOOL BUS CONVERSION SUMMARY

SCHOOL DIVISION DATA	
School Division	Norwood
No.:	8

VEHICLE DATA	
Number of Conversion Fleet Buses	2
Convs. Fleet Gasoline Displacement (litres)	31,666
Convs. Fleet Natural Gas Consumption (m3	30,411
Convs. Fleet Annual Distance (kilometres)	50,828

ASSUMPTIONS	
Fuel Prices	
Natural Gas Price ($/m3)	$0.880
Natural Gas Price Equivalent ($/litre eq.)	$0.118
Gasoline Price ($/litre)	$0.505
Fuel Price Difference	$0.387
Conversion Costs	
Conversion Kit	($2,500.00)
Tanks	($3,000.00)
Labour	Included
Total (plus GST & PST)	($6,008.20)
Operating Cost	
Station Maintenance ($/L eq.)	($0.04)
Power ($/L eq.)	($0.01)
Total	($0.05)
Training Expense	($750.00)
Discount Rate	5.00%
Analysis Period (Years)	13

EMISSIONS REDUCTIONS (Kilograms)	
Total Hydrocarbons (kg)	-337
Non-Methane Hydrocarbons (kg)	28
Carbon Monoxide (kg)	2,744
Nitrogen Oxides (kg)	112
Carbon Dioxide (kg)	51,801

ECONOMIC ANALYSIS RESULTS	NPV	ANNUALIZED
COSTS		
CONVERSION COSTS		
Total Conversion Cost	($12,016.40)	
Amortized Conversion Cost		($1,279.22)
REFUELING FACILITY		
Capital Cost (Including Salvage)	($152,273.54)	
Amortized Refueling Facility		($17,443.84)
TRAINING EXPENSES	($750.00)	
Amortized Training Expenses		($79.84)
OPERATING EXPENSES	($14,724.12)	
Total Annual Operating Expenses		($1,567.47)
TOTAL COSTS		
Total Capital and Training Costs	($165,039.94)	
Present Value Operating Costs	($14,724.12)	
Present Value of Costs	($179,764.05)	
Total Annual Amortization and Operating Expenses Cash Flow		($20,370.37)
SAVINGS		
FUEL EXPENSE SAVINGS		
Present Value of Savings	$100,533.58	
Annual Fuel Savings		$10,702.38
RESULTS		
Net Present Value	($79,230.47)	
Net Financial Annual Savings		($9,667.99)

SENSITIVITIES (To Result In Net Present Value = $0.00)		
Factor	Value	Change
Natural Gas Price Equivalent ($/litre ec	($0.15)	-229%
Gasoline Price ($/litre)	$0.80	59%
Conversion Cost Per Unit	($33,607.00)	-659%
Refueling Facilities	$78,601.00	-48%
Discount Rate	-2.76%	-155%

Economic Analysis of NGV Conversion
School Division Norwood

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Salvage
COSTS															
CONVERSION COSTS															
No. of Bus Conversions	2														
Cost per Conversion	($6,008)														
Total Conversion Cost	($12,016)														
Amortized Conversion Cost		($1,279)	($1,279)	($1,279)	($1,279)	($1,279)	($1,279)	($1,279)	($1,279)	($1,279)	($1,279)	($1,279)	($1,279)	($1,279)	$0
REFUELING FACILITY															
Natural Gas Consumption (l eq.)	31,349														
Capital Cost	($163,860)														
Amortized Refueling Facility		($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	$21,848
Present Value of Salvage	$11,586														
TRAINING EXPENSES	($750)														
Amortized Training Expenses		($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	
OPERATING EXPENSES															
Natural Gas Cons. (gasoline l. eq.)		31,349	31,349	31,349	31,349	31,349	31,349	31,349	31,349	31,349	31,349	31,349	31,349	31,349	
Station Maintenance		($1,254)	($1,254)	($1,254)	($1,254)	($1,254)	($1,254)	($1,254)	($1,254)	($1,254)	($1,254)	($1,254)	($1,254)	($1,254)	
Power		($313)	($313)	($313)	($313)	($313)	($313)	($313)	($313)	($313)	($313)	($313)	($313)	($313)	
Total Annual Operating Expenses		($1,567)	($1,567)	($1,567)	($1,567)	($1,567)	($1,567)	($1,567)	($1,567)	($1,567)	($1,567)	($1,567)	($1,567)	($1,567)	
TOTAL COSTS															
Total Capital and Training Costs	($165,040)														
Present Value Operating Costs	($14,724)														
Present Value of Costs	($179,764)														
Total Annualized Costs and Operating Expenses		($20,370)	($20,370)	($20,370)	($20,370)	($20,370)	($20,370)	($20,370)	($20,370)	($20,370)	($20,370)	($20,370)	($20,370)	($20,370)	
SAVINGS															
FUEL EXPENSE SAVINGS AFTER CONVERSION															
Natural Gas Consumption (m³)		30,411	30,411	30,411	30,411	30,411	30,411	30,411	30,411	30,411	30,411	30,411	30,411	30,411	
Gasoline Consumption		3,167	3,167	3,167	3,167	3,167	3,167	3,167	3,167	3,167	3,167	3,167	3,167	3,167	
Total Fuel Savings Cash Flow		$10,702	$10,702	$10,702	$10,702	$10,702	$10,702	$10,702	$10,702	$10,702	$10,702	$10,702	$10,702	$10,702	
Present Value of Savings	$100,534														
PRESENT VALUE AND NET ANNUALIZED SAVINGS															
Net Present Value	($79,230)														
Net Annualized Savings		($9,668)	($9,668)	($9,668)	($9,668)	($9,668)	($9,668)	($9,668)	($9,668)	($9,668)	($9,668)	($9,668)	($9,668)	($9,668)	

Emissions Analysis of NGV Conversion
School Division Norwood

Category	Totals	Year												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Total Conversion Kilometres	660,758	50,828	50,828	50,828	50,828	50,828	50,828	50,828	50,828	50,828	50,828	50,828	50,828	50,828
Total Hydrocarbons (kg)	-337	-25.90	-25.90	-25.90	-25.90	-25.90	-25.90	-25.90	-25.90	-25.90	-25.90	-25.90	-25.90	-25.90
Non-Methane Hydrocarbons (kg)	28	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19	2.19
Carbon Monoxide (kg)	2,744	211.11	211.11	211.11	211.11	211.11	211.11	211.11	211.11	211.11	211.11	211.11	211.11	211.11
Nitrogen Oxides (kg)	112	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59	8.59
Carbon Dioxide (kg)	51,801	3,984.70	3,984.70	3,984.70	3,984.70	3,984.70	3,984.70	3,984.70	3,984.70	3,984.70	3,984.70	3,984.70	3,984.70	3,984.70

NGV SCHOOL BUS CONVERSION SUMMARY

SCHOOL DIVISION DATA	
School Division	Pelly Trail
No.:	37

VEHICLE DATA	
Number of Conversion Fleet Buses	8
Convs. Fleet Gasoline Displacement (litres)	69,709
Convs. Fleet Natural Gas Consumption (m3	66,946
Convs. Fleet Annual Distance (kilometres)	136,985

ASSUMPTIONS	
Fuel Prices	
Natural Gas Price ($/m3)	$0.880
Natural Gas Price Equivalent ($/litre eq.)	$0.118
Gasoline Price ($/litre)	$0.505
Fuel Price Difference	$0.387
Conversion Costs	
Conversion Kit	($2,500.00)
Tanks	($3,000.00)
Labour	Included
Total (plus GST & PST)	($6,008.20)
Operating Cost	
Station Maintenance ($/L eq.)	($0.04)
Power ($/L eq.)	($0.01)
Total	($0.05)
Training Expense	($750.00)
Discount Rate	5.00%
Analysis Period (Years)	13

EMISSIONS REDUCTIONS (Kilograms)	
Total Hydrocarbons (kg)	-908
Non-Methane Hydrocarbons (kg)	77
Carbon Monoxide (kg)	7,397
Nitrogen Oxides (kg)	301
Carbon Dioxide (kg)	139,609

ECONOMIC ANALYSIS RESULTS	NPV	ANNUALIZED
COSTS		
CONVERSION COSTS		
Total Conversion Cost	($48,065.60)	
Amortized Conversion Cost		($5,116.86)
REFUELING FACILITY		
Capital Cost (Including Salvage)	($152,273.54)	
Amortized Refueling Facility		($17,443.84)
TRAINING EXPENSES	($750.00)	
Amortized Training Expenses		($79.84)
OPERATING EXPENSES	($32,413.42)	
Total Annual Operating Expenses		($3,450.60)
TOTAL COSTS		
Total Capital and Training Costs	($201,089.14)	
Present Value Operating Costs	($32,413.42)	
Present Value of Costs	($233,502.56)	
Total Annual Amortization and Operating Expenses Cash Flow		($26,091.14)
SAVINGS		
FUEL EXPENSE SAVINGS		
Present Value of Savings	$221,312.94	
Annual Fuel Savings		$23,560.04
RESULTS		
Net Present Value	($12,189.62)	
Net Financial Annual Savings		($2,531.10)

SENSITIVITIES (To Result in Net Present Value = $0.00)		
Factor	Value	Change
Natural Gas Price Equivalent ($/litre eq	$0.10	-16%
Gasoline Price ($/litre)	$0.53	4%
Conversion Cost Per Unit	$4,484.50	-25%
Refueling Facilities	$150,743.00	-1%
Discount Rate	4.09%	-18%

Economic Analysis of NGV Conversion
School Division Pelly Trail

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Salvage
COSTS															
CONVERSION COSTS															
No. of Bus Conversions	8														
Cost per Conversion	($6,008)														
Total Conversion Cost	($48,066)														
Amortized Conversion Cost		($5,117)	($5,117)	($5,117)	($5,117)	($5,117)	($5,117)	($5,117)	($5,117)	($5,117)	($5,117)	($5,117)	($5,117)	($5,117)	$0
REFUELING FACILITY															
Natural Gas Consumption (l eq.)	69,012														
Capital Cost	($163,860)														
Amortized Refueling Facility		($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	($17,444)	$21,848
Present Value of Salvage	$11,586														
TRAINING EXPENSES	($750)														
Amortized Training Expenses		($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	
OPERATING EXPENSES															
Natural Gas Cons. (gasoline l. eq.)		69,012	69,012	69,012	69,012	69,012	69,012	69,012	69,012	69,012	69,012	69,012	69,012	69,012	
Station Maintenance		($2,760)	($2,760)	($2,760)	($2,760)	($2,760)	($2,760)	($2,760)	($2,760)	($2,760)	($2,760)	($2,760)	($2,760)	($2,760)	
Power		($690)	($690)	($690)	($690)	($690)	($690)	($690)	($690)	($690)	($690)	($690)	($690)	($690)	
Total Annual Operating Expenses		($3,451)	($3,451)	($3,451)	($3,451)	($3,451)	($3,451)	($3,451)	($3,451)	($3,451)	($3,451)	($3,451)	($3,451)	($3,451)	
TOTAL COSTS															
Total Capital and Training Costs	($201,089)														
Present Value Operating Costs	($32,413)														
Present Value of Costs	($233,503)														
Total Annualized Costs and Operating Expenses		($26,091)	($26,091)	($26,091)	($26,091)	($26,091)	($26,091)	($26,091)	($26,091)	($26,091)	($26,091)	($26,091)	($26,091)	($26,091)	
SAVINGS															
FUEL EXPENSE SAVINGS AFTER CONVERSION															
Natural Gas Consumption (m^3)		66,946	66,946	66,946	66,946	66,946	66,946	66,946	66,946	66,946	66,946	66,946	66,946	66,946	
Gasoline Consumption		6,971	6,971	6,971	6,971	6,971	6,971	6,971	6,971	6,971	6,971	6,971	6,971	6,971	
Total Fuel Savings Cash Flow		$23,560	$23,560	$23,560	$23,560	$23,560	$23,560	$23,560	$23,560	$23,560	$23,560	$23,560	$23,560	$23,560	
Present Value of Savings	$221,313														
PRESENT VALUE AND NET ANNUALIZED SAVINGS															
Net Present Value	($12,190)														
Net Annualized Savings		($2,531)	($2,531)	($2,531)	($2,531)	($2,531)	($2,531)	($2,531)	($2,531)	($2,531)	($2,531)	($2,531)	($2,531)	($2,531)	

Emissions Analysis of NGV Conversion
School Division Pelly Trail

Category	Totals	Year												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Total Conversion Kilometres	1,780,810	136,985	136,985	136,985	136,985	136,985	136,985	136,985	136,985	136,985	136,985	136,985	136,985	136,985
Total Hydrocarbons (kg)	-908	-69.81	-69.81	-69.81	-69.81	-69.81	-69.81	-69.81	-69.81	-69.81	-69.81	-69.81	-69.81	-69.81
Non-Methane Hydrocarbons (kg)	77	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89	5.89
Carbon Monoxide (kg)	7,397	568.97	568.97	568.97	568.97	568.97	568.97	568.97	568.97	568.97	568.97	568.97	568.97	568.97
Nitrogen Oxides (kg)	301	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16	23.16
Carbon Dioxide (kg)	139,609	10,739.18	10,739.18	10,739.18	10,739.18	10,739.18	10,739.18	10,739.18	10,739.18	10,739.18	10,739.18	10,739.18	10,739.18	10,739.18

NGV SCHOOL BUS CONVERSION SUMMARY

SCHOOL DIVISION DATA	
School Division	St. Vital
No.:	6

VEHICLE DATA	
Number of Conversion Fleet Buses	23
Convs. Fleet Gasoline Displacement (litres)	191,820
Convs. Fleet Natural Gas Consumption (m3	184,216
Convs. Fleet Annual Distance (kilometres)	539,939

ASSUMPTIONS	
Fuel Prices	
Natural Gas Price ($/m3)	$0.880
Natural Gas Price Equivalent ($/litre eq.)	$0.118
Gasoline Price ($/litre)	$0.490
Fuel Price Difference	$0.372
Conversion Costs	
Conversion Kit	($2,500.00)
Tanks	($3,000.00)
Labour	Included
Total (plus GST & PST)	($6,008.20)
Operating Cost	
Station Maintenance ($/L eq.)	($0.04)
Power ($/L eq.)	($0.01)
Total	($0.05)
Training Expense	($750.00)
Discount Rate	5.00%
Analysis Period (Years)	13

EMISSIONS REDUCTIONS (Kilograms)	
Total Hydrocarbons (kg)	-3,577
Non-Methane Hydrocarbons (kg)	302
Carbon Monoxide (kg)	29,154
Nitrogen Oxides (kg)	1,187
Carbon Dioxide (kg)	550,281

ECONOMIC ANALYSIS RESULTS	NPV	ANNUALIZED
COSTS		
CONVERSION COSTS		
Total Conversion Cost	($138,188.60)	
Amortized Conversion Cost		($14,710.97)
REFUELING FACILITY		
Capital Cost (Including Salvage)	($228,410.31)	
Amortized Refueling Facility		($26,165.76)
TRAINING EXPENSES	($750.00)	
Amortized Training Expenses		($79.84)
OPERATING EXPENSES	($89,192.82)	
Total Annual Operating Expenses		($9,496.09)
TOTAL COSTS		
Total Capital and Training Costs	($367,348.91)	
Present Value Operating Costs	($89,192.82)	
Present Value of Costs	($456,541.73)	
Total Annual Amortization and Operating Expenses Cash Flow		($50,451.67)
SAVINGS		
FUEL EXPENSE SAVINGS		
Present Value of Savings	$584,667.05	
Annual Fuel Savings		$62,241.18
RESULTS		
Net Present Value	$128,125.32	
Net Financial Annual Savings		$11,789.51

SENSITIVITIES (To Result In Net Present Value = $0.00)		
Factor	Value	Change
Natural Gas Price Equivalent ($/litre eq	$0.19	61%
Gasoline Price ($/litre)	$0.41	-16%
Conversion Cost Per Unit	$11,599.08	93%
Refueling Facilities	$384,165.00	68%
Discount Rate	9.90%	98%

Economic Analysis of NGV Conversion
School Division St. Vital

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Salvage
COSTS															
CONVERSION COSTS															
No. of Bus Conversions	23														
Cost per Conversion	($6,006)														
Total Conversion Cost	($138,138)														
Amortized Conversion Cost		($14,711)	($14,711)	($14,711)	($14,711)	($14,711)	($14,711)	($14,711)	($14,711)	($14,711)	($14,711)	($14,711)	($14,711)	($14,711)	$0
REFUELING FACILITY															
Natural Gas Consumption (l eq.)	189,902														
Capital Cost	($245,790)														
Amortized Refueling Facility		($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	$32,772
Present Value of Salvage	$17,380														
TRAINING EXPENSES	($750)														
Amortized Training Expenses		($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	
OPERATING EXPENSES															
Natural Gas Cons. (gasoline l. eq.)		189,902	189,902	189,902	189,902	189,902	189,902	189,902	189,902	189,902	189,902	189,902	189,902	189,902	
Station Maintenance		($7,596)	($7,596)	($7,596)	($7,596)	($7,596)	($7,596)	($7,596)	($7,596)	($7,596)	($7,596)	($7,596)	($7,596)	($7,596)	
Power		($1,899)	($1,899)	($1,899)	($1,899)	($1,899)	($1,899)	($1,899)	($1,899)	($1,899)	($1,899)	($1,899)	($1,899)	($1,899)	
Total Annual Operating Expenses		($9,495)	($9,495)	($9,495)	($9,495)	($9,495)	($9,495)	($9,495)	($9,495)	($9,495)	($9,495)	($9,495)	($9,495)	($9,495)	
TOTAL COSTS															
Total Capital and Training Costs	($367,349)														
Present Value Operating Costs	($89,193)														
Present Value of Costs	($456,542)														
Total Annualized Costs and Operating Expenses		($50,452)	($50,452)	($50,452)	($50,452)	($50,452)	($50,452)	($50,452)	($50,452)	($50,452)	($50,452)	($50,452)	($50,452)	($50,452)	
SAVINGS															
FUEL EXPENSE SAVINGS AFTER CONVERSION															
Natural Gas Consumption (m^3)		184,216	184,216	184,216	184,216	184,216	184,216	184,216	184,216	184,216	184,216	184,216	184,216	184,216	
Gasoline Consumption		19,182	19,182	19,182	19,182	19,182	19,182	19,182	19,182	19,182	19,182	19,182	19,182	19,182	
Total Fuel Savings Cash Flow		$62,241	$62,241	$62,241	$62,241	$62,241	$62,241	$62,241	$62,241	$62,241	$62,241	$62,241	$62,241	$62,241	
Present Value of Savings	$584,667														
PRESENT VALUE AND NET ANNUALIZED SAVINGS															
Net Present Value	$128,125														
Net Annualized Savings		$11,790	$11,790	$11,790	$11,790	$11,790	$11,790	$11,790	$11,790	$11,790	$11,790	$11,790	$11,790	$11,790	

Emissions Analysis of NGV Conversion
School Division St. Vital

Category	Totals	Year												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Total Conversion Kilometres	7,019,204	539,939	539,939	539,939	539,939	539,939	539,939	539,939	539,939	539,939	539,939	539,939	539,939	539,939
Total Hydrocarbons (kg)	-3,577	-275.17	-275.17	-275.17	-275.17	-275.17	-275.17	-275.17	-275.17	-275.17	-275.17	-275.17	-275.17	-275.17
Non-Methane Hydrocarbons (kg)	302	23.22	23.22	23.22	23.22	23.22	23.22	23.22	23.22	23.22	23.22	23.22	23.22	23.22
Carbon Monoxide (kg)	29,154	2,242.64	2,242.64	2,242.64	2,242.64	2,242.64	2,242.64	2,242.64	2,242.64	2,242.64	2,242.64	2,242.64	2,242.64	2,242.64
Nitrogen Oxides (kg)	1,187	91.28	91.28	91.28	91.28	91.28	91.28	91.28	91.28	91.28	91.28	91.28	91.28	91.28
Carbon Dioxide (kg)	550,281	42,329.32	42,329.32	42,329.32	42,329.32	42,329.32	42,329.32	42,329.32	42,329.32	42,329.32	42,329.32	42,329.32	42,329.32	42,329.32

NGV SCHOOL BUS CONVERSION SUMMARY

SCHOOL DIVISION DATA	
School Division:	0
No.:	0

VEHICLE DATA	
Number of Conversion Fleet Buses	14
Convs. Fleet Gasoline Displacement (litres)	90,009
Convs. Fleet Natural Gas Consumption (m3)	86,441
Convs. Fleet Annual Distance (kilometres)	131,040

ASSUMPTIONS	
Fuel Prices	
Natural Gas Price ($/m3)	$0.880
Natural Gas Price Equivalent ($/litre eq.)	$0.118
Gasoline Price ($/litre)	$0.505
Fuel Price Difference	$0.387
Conversion Costs	
Conversion Kit	($2,500.00)
Tanks	($3,000.00)
Labour	Included
Total (plus GST & PST)	($6,008.20)
Operating Cost	
Station Maintenance ($/L eq.)	($0.04)
Power ($/L eq.)	($0.01)
Total	($0.05)
Training Expense	($750.00)
Discount Rate	5.00%
Analysis Period (Years)	13

EMISSIONS REDUCTIONS (Kilograms)	
Total Hydrocarbons (kg)	-868
Non-Methane Hydrocarbons (kg)	73
Carbon Monoxide (kg)	7,076
Nitrogen Oxides (kg)	288
Carbon Dioxide (kg)	133,550

ECONOMIC ANALYSIS RESULTS	NPV	ANNUALIZED
COSTS		
CONVERSION COSTS		
Total Conversion Cost	($84,114.80)	
Amortized Conversion Cost		($8,954.51)
REFUELING FACILITY		
Capital Cost (Including Salvage)	($228,410.31)	
Amortized Refueling Facility		($26,165.76)
TRAINING EXPENSES	($750.00)	
Amortized Training Expenses		($79.84)
OPERATING EXPENSES	($41,852.71)	
Total Annual Operating Expenses		($4,455.46)
TOTAL COSTS		
Total Capital and Training Costs	($313,275.11)	
Present Value Operating Costs	($41,852.71)	
Present Value of Costs	($355,127.82)	
Total Annual Amortization and Operating Expenses Cash Flow		($39,655.57)
SAVINGS		
FUEL EXPENSE SAVINGS		
Present Value of Savings	$285,762.68	
Annual Fuel Savings		$30,421.08
RESULTS		
Net Present Value	($69,365.14)	
Net Financial Annual Savings		($9,234.49)

SENSITIVITIES (To Result in Net Present Value = $0.00)		
Factor	Value	Change
Natural Gas Price Equivalent ($/litre eq.)	$0.03	-70%
Gasoline Price ($/litre)	$0.60	18%
Conversion Cost Per Unit	$1,053.55	-82%
Refueling Facilities	$171,147.88	-25%
Discount Rate	1.54%	-69%

NGV SCHOOL BUS ANALYSIS DATA

School Division:	
No.:	
Mailing Address:	
Contact:	
Title:	

School Bus Data							
Bus	Year	Fuel Type	Seating Capacity	Daily Route (km)	Yearly kilometres	Annual Fuel Consumption	Gasoline Equivalent[1]
1	1993	Diesel	16	48	10,400	6,120	7,583
2	1988	Diesel	14	46	10,400	6,120	7,583
3	1988	Diesel	7	57	10,400	6,120	7,583
4	1987	Gasoline	48	53	10,400	6,120	6,120
5	1987	Gasoline	72	68	10,400	6,120	6,120
6	1987	Gasoline	72	35	10,400	6,120	6,120
7	1987	Gasoline	66	42	10,400	6,120	6,120
8	1987	Gasoline	66	90	10,400	6,120	6,120
9	1987	Gasoline	65	60	10,400	6,120	6,120
10	1988	Gasoline	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
11	1988	Gasoline	66	15	10,400	6,120	6,120
12	1988	Gasoline	66	58	10,400	6,120	6,120
13	1988	Gasoline	66	61	10,400	6,120	6,120
14	1988	Gasoline	66	60	10,400	6,120	6,120
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Totals	N/A	N/A	N/A	734	145,600	85,680	90,069

Notes:

1. Gasoline equivalent equals 1/(34.66 MJ higher heating value for gasoline / 38.68 MJ higher heating value for diesel fuel).

NGV SCHOOL BUS ANALYSIS ASSUMPTIONS

FUEL PRICES (including taxes)	
Natural Gas Price/m^3	$0.8800
Natural Gas Price Equivalent:	$0.1177
Gasoline Price/litre	$0.5050

VEHICLE COST	
Conversion Kit	($2,500.00)
Tanks	($3,000.00)
Labour	Included
Total (plus GST & PST)	($6,008.20)

OPERATING COST	
Station Maintenance ($/L eq.)	($0.04)
Power ($/L eq.)	($0.01)
Total	($0.05)

TRAINING EXPENSE	($750)

REAL DISCOUNT RATE:	5.00%
ANALYSIS PERIOD (YEARS):	13
FUEL SUBSTITUTION RATE	90%

STATION DESIGN			
	Small	Medium	Large
Total	($163,860)	($245,790)	($327,720)

VEHICLE EFFICIENCY	
NGV Fuel Efficiency Penalty	10%

Assumptions - Grams Per Kilometre*				
Emission	CNG	Gasoline	Emissions Reduction	Percent Reduction
THC	0.936	0.426	-0.510	-119.53%
NMHC	0.021	0.064	0.043	67.00%
CO	0.257	4.411	4.154	94.17%
NOx	0.867	1.036	0.169	16.32%
CO2	278.135	356.532	78.397	21.99%
* From Lyons and McCoy, 1993, p. 26.				

ENERGY EQUIVALENTS	
Natural Gas:	
Density	0.693 kg/m^3
Lower Heating Value (LHV)	33.40 megajoules/m^3 (MJ/m^3)
Gasoline:	
Lower Heating Value	32.40 MJ/L

Diesel

Lower Heating Value 36.40 MJ/L

The mass of natural gas required to replace an equal amount of energy in a litre of gasoline is:

MJ/L (gasoline) X m^3 / MJ (natural gas) X kg / m^3 (density of natural gas) =
kg (natural gas / L (gasoline)

1 Litre of unleaded gasoline (energy equivalent) = 0.6769 kg of natural gas

Similarly, the mass of natural gas that is required to replace a litre of diesel is:

MJ/L (diesel) X m^3 / MJ (natural gas) X kg / m^3 (density of natural gas) =
kg (natural gas / L (diesel)

1 Litre of diesel (energy equivalent) = 0.7605 kg of natural gas

NGV SCHOOL BUS ANALYSIS CONVERSION FLEET

CONVERSION FLEET AND FUEL REQUIREMENTS	
Buses in Conversion Fleet	14
Total Gasoline Consumption (litres)	90,009
Total Gasoline Consumption (megajoules)	2,916,302
Post Conversion Gasoline Consumption	9,001
Volume of Natural Gas Required (m3)	86,441
Natural Gas Gasoline Equivalent	89,109
Cummulative Annual Savings	$30,421
Cummulative Kilometres On Natural Gas	131,040

School Bus Data						
Bus	Year	Fuel Type	Seating Capacity	Daily Route (km)	Annual kilometres	Annual Fuel Consumption
1	1983	Diesel	16	48	10,400	7,563
2	1988	Diesel	14	46	10,400	7,563
3	1988	Diesel	7	52	10,400	7,563
4	1987	Gasoline	48	53	10,400	6,120
5	1987	Gasoline	72	68	10,400	6,120
6	1987	Gasoline	72	25	10,400	6,120
7	1987	Gasoline	66	42	10,400	6,120
8	1987	Gasoline	66	90	10,400	6,120
9	1987	Gasoline	66	60	10,400	6,120
10	1988	Gasoline	14	52	10,400	6,120
11	1988	Gasoline	66	19	10,400	6,120
12	1988	Gasoline	66	58	10,400	6,120
13	1988	Gasoline	66	61	10,400	6,120
14	1988	Gasoline	66	60	10,400	6,120
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Annual Fuel Cost Savings	Break-even Test
$2,556.16	Pass
$2,556.16	Pass
$2,556.16	Pass
$2,068.42	Pass
$2,068.42	Pass
$2,068.42	Pass
$2,068.42	Pass
$2,068.42	Pass
$2,068.42	Pass
$2,068.42	Pass
$2,068.42	Pass
$2,068.42	Pass
$2,068.42	Pass
$2,068.42	Pass

Economic Analysis of NGV Conversion
School Division: 0

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	Salvage
COSTS															
CONVERSION COSTS															
No. of Bus Conversions	14														
Cost per Conversion	($6,008)														
Total Conversion Cost	($84,115)														
Amortized Conversion Cost		($8,955)	($8,955)	($8,955)	($8,955)	($8,955)	($8,955)	($8,955)	($8,955)	($8,955)	($8,955)	($8,955)	($8,955)	($8,955)	$0
REFUELING FACILITY															
Natural Gas Consumption (l eq)	89,109														
Capital Cost	($245,790)														
Amortized Refueling Facility		($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	($26,166)	$32,772
Present Value of Salvage	$17,380														
TRAINING EXPENSES	($750)														
Amortized Training Expenses		($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	($80)	
OPERATING EXPENSES															
Natural Gas Cons. (gasoline l. eq)		89,109	89,109	89,109	89,109	89,109	89,109	89,109	89,109	89,109	89,109	89,109	89,109	89,109	
Station Maintenance		($3,564)	($3,564)	($3,564)	($3,564)	($3,564)	($3,564)	($3,564)	($3,564)	($3,564)	($3,564)	($3,564)	($3,564)	($3,564)	
Power		($891)	($891)	($891)	($891)	($891)	($891)	($891)	($891)	($891)	($891)	($891)	($891)	($891)	
Total Annual Operating Expenses		($4,455)	($4,455)	($4,455)	($4,455)	($4,455)	($4,455)	($4,455)	($4,455)	($4,455)	($4,455)	($4,455)	($4,455)	($4,455)	
TOTAL COSTS															
Total Capital and Training Costs	($313,275)														
Present Value Operating Costs	($41,853)														
Present Value of Costs	($355,128)														
Total Annualized Costs and Operating Expenses		($39,656)	($39,656)	($39,656)	($39,656)	($39,656)	($39,656)	($39,656)	($39,656)	($39,656)	($39,656)	($39,656)	($39,656)	($39,656)	
SAVINGS															
FUEL EXPENSE SAVINGS															
AFTER CONVERSION															
Natural Gas Consumption (m^3)		86,441	86,441	86,441	86,441	86,441	86,441	86,441	86,441	86,441	86,441	86,441	86,441	86,441	
Gasoline Consumption		9,001	9,001	9,001	9,001	9,001	9,001	9,001	9,001	9,001	9,001	9,001	9,001	9,001	
Total Fuel Savings Cash Flow		$30,421	$30,421	$30,421	$30,421	$30,421	$30,421	$30,421	$30,421	$30,421	$30,421	$30,421	$30,421	$30,421	
Present Value of Savings	$285,763														
PRESENT VALUE AND NET ANNUALIZED SAVINGS															
Net Present Value	($69,365)														
Net Annualized Savings		($9,234)	($9,234)	($9,234)	($9,234)	($9,234)	($9,234)	($9,234)	($9,234)	($9,234)	($9,234)	($9,234)	($9,234)	($9,234)	

Emissions Analysis of NGV Conversion
School Division: 0

Category	Totals	Year												
		1	2	3	4	5	6	7	8	9	10	11	12	13
Total Conversion Kilometres	1,703,520	131,040	131,040	131,040	131,040	131,040	131,040	131,040	131,040	131,040	131,040	131,040	131,040	131,040
Total Hydrocarbons (kg)	-868	-66 78	-66 78	-66 78	-66 78	-66 78	-66 78	-66 78	-66 78	-66 78	-66 78	-66 78	-66 78	-66 78
Non-Methane Hydrocarbons (kg)	73	5 63	5 63	5 63	5 63	5 63	5 03	5 63	5 63	5 63	5 63	5 63	5 63	5 63
Carbon Monoxide (kg)	7,076	544 28	544 28	544 28	544 28	544 28	544 28	544 28	544 28	544 28	544 28	544 28	544 28	544 28
Nitrogen Oxides (kg)	288	22 15	22 15	22 15	22 15	22 15	22 15	22 15	22 15	22 15	22 15	22 15	22 15	22 15
Carbon Dioxide (kg)	133,550	10,273 08	10,273 08	10,273 08	10,273 08	10,273 08	10,273 08	10,273 08	10,273 08	10,273 08	10,273 08	10,273 08	10,273 08	10,273 08