AN ASSESSMENT OF THE ECONOMIC AND ADMINISTRATIVE FEASIBILITY OF SUBSTITUTING PROPANE FOR GASOLINE IN THE UNIVERSITY OF MANITOBA AUTOMOTIVE FLEET

By
Lewis McCall

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

Natural Resources Institute
The University of Manitoba
Winnipeg, Manitoba, Canada
April, 1983

ABSTRACT

The rapid and significant increases in energy costs that have occurred in recent years are necessarily of concern to those responsible for the management of a large energy consumer such as the University of Manitoba. Following a survey of the supply, distribution, technology and price of a number of alternative fuels, this study focussed on the viability of propane as a vehicle fuel option for the University of Manitoba in September, 1982.

A review of propane supply, distribution, conversion technology and price indicated reasonable prospects for a general environment favourable to the use of propane until the mid-1990's.

While based on price data as at September, 1982, the detailed economic analysis was performed largely in terms of volumes of gasoline that would be displaced through the use of propane. The analysis indicated that if only five of 98 University vehicles were converted to propane, the project would have a payback period of slightly under 38 months and an annual return of almost 30 per cent.

A review of potential non-economic benefits indicated that the project could provide University personnel with valuable experience in the implementation of a different energy technology and inter-departmental cooperation while at the same time enabling the University to serve as a source of information on locally operated propane fueled

vehicles and to assume a local leadership role in terms of oil conservation and air pollution control.

The study found that administrative adjustments required by the project need not pose a barrier to implementation. However, the manner of implementation was found to be crucial to the project's success. The study concluded that if management could accept the usefulness of small scale projects and if the project could be implemented in a non-threatening manner with respect to those directly affected, consideration should be given to a detailed evaluation of the entire University fleet with a view to converting a number of vehicles to propane.

ACKNOWLEDGEMENTS

This practicum was developed from a study performed in my position as an internal auditor at the University of Manitoba. I am indebted to many people directly and indirectly. Several of them will be found mentioned in the bibliography. In particular, I would like to acknowledge my indebtedness to the following:

The members of my practicum committee --

Mr. Jim Blomquist
Professor Thomas Henley
Dr. Walter Henson
Dr. Allan Lansdown
Professor David Young

for research material they supplied and for their time, advice, flexibility and patience. Their encouragement and efforts on my behalf have played a significant role in keeping my efforts moving toward the completion of this study.

Ms. Yvonne Penning

for her suggestion that I consider developing my original study into a practicum and for research material.

Dr. D. O. Wells, and
Mr. A. E. Johnson

for making it possible for me to utilize my original study material in the practicum.

Ms. Judith Gibson
Ms. Jan MacKinnon
Mr. David Mathers
Mr. Bob Parsons

for research material.

Mr. Martin Adelaar
Ms. Melanie Phillips
Mr. Bruce and Ms. Janet Smith
and my brothers and sister

for research material, comments and considerable moral support and encouragement during a very difficult period.

Ms. Diane Benoit
Ms. Emilie Novotny
Ms. Christine Hofer

for their efforts in producing the typed manuscript.

TABLE OF CONTENTS

Table of Contents (cont'd.) Page

CHAPTER III: PROPANE IN DETAIL

CHAPTER IV: EVALUATING THE VIABILITY OF PROPANE CONVERSION

Table of Contents (cont'd)

Table of Contents (cont'd.)

LIST OF TABLES

LIST OF FIGURES

CHAPTER I
INTRODUCTION

1.1 Background

1.1.1. *A Note on Petroleum Resources and Industrial Society*

Crude oil and natural gas are the liquid and gaseous components of petroleum. Petroleum is composed largely of hydrocarbons derived from organic materials that have been subjected to increased temperature and pressure, due to burial, for millions of years.[1] The time required for its formation means that for all practical purposes, the total quantity of petroleum resources is finite.[2] A second characteristic of petroleum is its tendency to migrate from its site of formation.[3] "Where barriers or traps are interposed in the migration paths, accumulations result."[4] As large accumulations develop, the pressures inside the traps increase. This type of pressure has been a key factor in the ability of humanity to extract liquid petroleum from the earth. A third characteristic of petroleum is its geographic distribution which is widespread but uneven.[5]

---

[1]Robert J. Foster, Geology, 3rd ed. (Columbus, Ohio: Charles E. Merrill Publishing Company, 1976), p. 89.

[2]M. King Hubbert, "The Energy Resources of the Earth" Energy and Power (A Scientific American Book). (San Francisco: W.H. Freeman and Company, 1971), p. 33.

[3]Brian J. Skinner, Earth Resources (Englewood Cliffs, New Jersey: Prentice-Hall Inc., 1969), p. 112.

[4]Ibid., p. 116.

[5]Ibid., p. 118.

Crude oil was the first component of petroleum that was exploited to fuel the industrialization of the twentieth century.[6]

The nature of the resource and the existence of certain philosophical orientations, socio-economic forces and institutional arrangements combined to produce oil supply gluts for a substantial part of the hundred-year period preceding 1970. The existence, easy accessibility and low cost of large volumes of oil favoured a technology dependent on oil. Since the period was one during which the rate of technological change was increasing, the potential uses and demand for oil rose exponentially in the industrialized nations of the world. For example, the annual growth rate of Canadian primary energy consumption -- energy measured at the point of production -- accelerated from a pre-World War II level of two to three per cent to rates of 4.2 per cent between 1945 and 1959, 5.6 per cent between 1960 and 1970 and 6.1 per cent between 1968 and 1973.[7] Between 1973 and 1977 the growth rate in primary energy consumption declined significantly, but erratically to an average of 2.4 per cent per year.[8] At the same time, the percentage of

---

[6]Indeed, the inability to handle and transport natural gas resulted in its being 'flared' at the site to facilitate the extraction of crude oil, well into the twentieth century.

[7]David B. Brooks, Zero Energy Growth for Canada (Toronto: McClelland and Stewart Limited, 1981), pp. 23 & 271.

[8]Ibid., p. 23.

primary energy consumption accounted for by oil rose from about 19 per cent in 1945 to around 30 per cent in 1950 and levelled off at approximately 45 per cent in 1960.[9] Further, with respect to energy use the transportation sector of the Canadian economy is largely dependent on one fuel -- oil.[10] During the 1960's, the growth rate of the transportation sector's secondary energy consumption -- energy measured at the point of consumption -- increased by an average of five per cent per year.[11] In 1977, the sector accounted for 42 per cent of oil consumption which, in turn, represented 52 per cent of Canadian secondary energy.[12] Within the transportation sector over-the-road modes of transport dominated energy demand consuming over 75 per cent of the sector's total secondary energy use.[13, 14]

Much of the expansion of oil dependency was fueled by the availability at very low prices of vast and easily

---

[9] Ibid., pp. 23-4

[10] Ibid., p. 35

[11] Ibid., pp. 35 and 271

[12] Ibid., pp. 31 and 35

[13] Ibid., p. 35

[14] Secondary energy is always less than primary energy because: (a) the energy-supply industry consumes or loses energy in processing and transportation; (b) some primary energy is used for non-energy products; and (c) about three units of fossil fuel must be consumed to generate one unit of thermally-generated electricity. See Brooks, <u>Zero Energy Growth for Canada</u>, pp. 270-2.

accessible oil reserves in the Middle East. A dependency on imported oil developed and the "...potential political curtailment of oil supply was an ever-present possibility."[15] Such curtailment would represent an effective if temporary simulation of the situation that could ultimately develop due to the physical depletion of the resource. In 1973, political curtailment of oil supplies accompanied by substantial price increases became a reality.

1.1.2 *The Canadian Situation after 1973*

Following the international oil price shock in 1973, the Canadian federal government regulated Canadian oil prices in accordance with the following considerations:

1. its "... commitment to a single price for crude oil in Canada, subject to transportation differences,
2. (its perceived need for) ... gradual increases in (the price of crude) in order to foster the development of new supplies and encourage conservation, and
3. (the perceived need to allow) Canadian consumers sufficient time to adjust to (the) higher prices."[16]

Between 1973 and the announcement of the National Energy

---

[15] Brooks, Zero Energy Growth, p. 28.

[16] Price Waterhouse, Chartered Accountants, The National Energy Program, 2nd ed. (n.p.: Price Waterhouse, Chartered Accountants, November, 1981), p. 34.

Program on October 28, 1980,

> ... Canadian oil price arrangements were based on federal-provincial pricing agreements which established a two price system for oil: the lower price ... being a domestic price and the higher price being an export price.[17]

Federal subsidies were paid out of general funds to refiners processing either imported or synthetic crude.[18] Between 1973 and December, 1980, the price of Canadian conventional crude increased almost five times from $3.40 to $16.75 per barrel. During the same period, Persian Gulf oil increased just over 17 times for $2.20 to $38.00 per barrel.[19] In short, at the beginning of the period, the price of Canadian oil was just over 1.5 times the international price while at the end of the period, it was less than half the international price.

> One of the objectives of the NEP was to ultimately shift the burden for those subsidies from the taxpayer at large to the oil consumer (through the introduction of the Petroleum Compensation Charge -- a levy on domestic refiners that is borne largely by consumers).[20]

This charge rose from $2.55 per barrel when initiated in late 1980 to $8.15 per barrel by August, 1981, immediately prior to the federal-Alberta pricing agreement of September, 1981.[21]

---

[17] Ibid., p. 36

[18] Ibid., p. 34 and 36

[19] Ibid., p. 34

[20] Ibid., p. 36

[21] Ibid., p. 17.

The energy pricing agreement between the federal and Alberta governments was followed by similar federal-provincial agreements with the governments of Saskatchewan and British Columbia.[22]

> Whereas the NEP originally established a new schedule of prices for domestic oil production and a new price system to blend the cost of different sources of oil into one weighted average price to consumers, the Alberta agreement initiate(d) a two-tier pricing system for crude oil.[23]

Canadian oil production was to be divided into "old oil"-- oil recovered from a pool initially discovered prior to January 1, 1981 -- and "new oil" --

> conventional oil recovered from pools initially discovered after December 31, 1980, incremental oil recovered with the use of enhanced recovery techniques...commencing after December 31, 1980, and crude bitumen produced from experimental and non-integrated oil sands projects commencing operation after December 31, 1980.[24]

The price of "old oil" would not be allowed to rise above 75% of the international price while the price of "new oil" would be allowed to rise to 100% of the international price. The prices, modified by the Petroleum Compensation Charge and increased by the Canadian Ownership Tax, would still provide consumers with a blended, weighted average price.[25]

---

[22]Ibid., p. 2

[23]Ibid., p. 34

[24]Ibid., pp. 34-35

[25]Ibid., p. 34

As indicated above, despite tightly controlled oil prices significantly lower than the international prices,[26] by mid-1982, Canadian consumers had been experiencing steadily and sharply increasing oil prices for almost a decade.

Between 1980 and mid-1982, a world economic recession, efforts by the oil-consuming nations to reduce demand and increase domestic supply, and the weakening of the cohesion of the OPEC cartel with respect to the control of production levels had led to a world oil glut and the levelling off of prices. (The established pricing arrangements and the wide discrepancy between domestic and international prices meant that Canadian prices continued to increase during most of this levelling off period). This type of phenomenon has characterized the oil market throughout its history and this history plus political and economic factors along with the prospect of declining conventional oil reserves make it seem likely that international oil prices will have resumed their upward movement by the mid-1980's. (The National Energy Program 1982 Update suggests that the upward movement of prices will begin by the end of 1983.)[27]

---

[26] Ibid., p. 4

[27] Canada, Department of Energy, Mines and Resources. The National Energy Program-Update 1982 (Ottawa: EMR, 1982), p.12.

1.1.3 *Response to the Oil Price/Supply Problem*

In response to the dramatic oil price increases during the period from October, 1973, till the end of 1980, a number of consuming nations including Canada took a variety of initiatives to reduce their dependence on the world oil market. Among the initiatives taken by the Canadian government were different types of "Oil Substitution" programs designed to encourage users to switch from high demand refined petroleum products to "alternative" fuels. One such program -- The Propane Vehicle Grant Program -- was designed to encourage the conversion of selected vehicles from gasoline to propane.

This type of initiative in combination with market forces such as the relative price of oil made alternative fuels such as propane appear attractive as a means of coping with current energy costs and the prospect of even higher prices in the future. This assessment was expressed succinctly by Roy F. Bennett, board chairman and chief executive of the Ford Motor Company of Canada, who indicated on October 16, 1981, that "Ford considers propane ... as the best of the alternative fuels for the rest of the 1980's."

1.2 The Problem Statement

The rapid and significant increases in energy costs that have occurred in recent years are necessarily of concern to those responsible for the management of a large energy consumer such as the University of Manitoba.

This research proposes to review the immediate viability of the propane vehicle fuel option for the University of Manitoba.

1.2.1 *The Sub-problems*

Evaluation of the viability of propane as an automotive fuel option is addressed in terms of the sub-problems listed below:

1. A number of potential alternative fuels are identified and reasons are offered for their elimination as candidates for more detailed investigation.

2. The current and prospective propane supply situations are reviewed in terms of the international, Canadian, regional and local markets.

3. The current price differential between propane and gasoline is identified and consideration is given to future price possibilities.

4. The technological viability of propane burning automotive equipment is reviewed in terms of:

    a) performance

    b) safety

    c) environmental factors

    d) maintenance and servicing

5. The costs of equipment associated with conversion are identified and discussed.

6. Maintenance cost factors associated with the use of propane technology are reviewed.

7. Certain non-economic factors associated with a conversion to propane burning automotive equipment are reviewed and their importance is discussed.

8. Financing possibilities that might be available to the University of Manitoba are identified and reviewed.

1.3 Delimitation of the Study

Due to time constraints, specific vehicle by vehicle evaluation of the entire University vehicle fleet will not be attempted. Selected data will be used for illustrative purposes.

1.4 Study Objectives

1. The first objective is to organize the economic data in a format that will enable the identification of break-even volume(s) and/or mileage with respect to the adoption of propane technology.

2. The second objective is to evaluate the importance that should be given to non-economic factors in any decision to adopt propane technology for use in certain University vehicles.

1.5 Methodology

1. Information for this study is drawn from relevant literature, through discussion with individuals and from University of Manitoba records.

2. The information obtained is organized in terms of the relevant sub-problems. Through a review of literature and discussion with various individuals relevant factors are identified and a number of assumptions are then used to develop break-even table(s) to be used in evaluating the economic aspects of utilizing propane technology.

3. Information regarding non-economic aspects of conversion are analyzed and conclusions drawn.

4. A summary analysis and conclusion are presented.

1.6 Importance of the Study

As the price of oil continues to rise and other alternative technologies are developed and/or become economic, further opportunities to reduce the increases in operating costs will arise. The methodology developed and outlined in this study will offer guidance for the evaluation of these technologies.

1.7 Assumed Characteristics of the Proposed User

Regardless of the theoretical possibilities of any innovation (e.g., an alternative automotive fuel), its applicability to a particular situation depends on the characteristics of the user organization for which its use is being considered. Accordingly, for the purpose of the analysis presented in this work the University of Manitoba is assumed to have the following characteristics:

1. The main campus, which was initially an agricultural college, covers an area of about 274 hectares[28] and is located in the district of Fort Garry in the south end of Winnipeg.

2. The Medical College associated with the University of Manitoba is located at the Health Sciences complex in central Winnipeg.

---

[28]The acreage figures were obtained by telephone from a representative of the Campus Planning Office.

3. The Fort Garry campus contains about 10.3 kilometers of private roads and 1.8 kilometers of roads maintained by the City of Winnipeg.[29]

4. The distance between the Fort Garry Campus and the Medical College campus is about 13 kilometers.[30]

5. There are assumed to be at least 98 vehicles[31] in the University fleet.

6. During the University's 1981-2 fiscal period (April 1, 1981, to March 31, 1982) - 98 University-owned vehicles were reported to have consumed 307,612 liters of vehicle fuel of which 181,418 liters (59 per cent) were obtained through bulk fuel purchases and 126,194 liters (41 per cent) were purchased from commercial fuel facilities off-campus.[32]

7. The maintenance and servicing of vehicles by staff of the University's central garage is restricted to vehicles under the control of the Physical Plant and Energy Management Department and one vehicle controlled by the Medical College. Other departments that control vehicles make their own maintenance and servicing arrangements.[33] A larger operation, for example the Department of Plant Science, might have its own staff, while smaller operations would not.

---

[29] Ibid.

[30] Distance was measured on the trip odometer of the researcher's car from the Physical Plant and Energy Management Building at Freedman Crescent and Kings Drive to the Chown Building at the corner of McDermot Avenue and Emily Street.

[31] The number of vehicles could not be established with greater accuracy because there were discrepancies among figures obtained from three sources. No two sources were in agreement.

[32] This information was drawn from the University's 1981-2 'Application for Refund of Federal Excise Tax on Gasoline' and the working papers that supported the application.

[33] This information was obtained through discussion with a member of the supervisory staff at the Physical Plant and Energy Management Department.

8. Inquiries failed to produce a written policy with respect to vehicle replacement and the researcher has been forced to conclude that none exists. The vehicle replacement policy that appears to be in practice can best be described as "running the vehicles into the ground." This may be at least partially due to the financial constraints under which the University has operated for several years.

9. The University's fiscal arrangements require the segregation of 'operating' and 'capital' expenditures and based on the author's observations over a seven-year period, it would appear that certain inconsistencies exist in the determination of governmental financial support as expressed through the 'operating' and 'capital' grants allocated to the University. (These inconsistencies are at least partially due to the failure to recognize the effects of inflation on capital replacement and maintenance).

10. The University has operated under severe financial constraints for several years and this situation is not expected to change in the near future.

CHAPTER II

SURVEY OF ALTERNATIVE FUELS

2.1 Introduction

Prior to the rise to dominance of the internal combustion engine, that began with a European automobile race in 1895,[1] "Steam, electric and gasoline-powered cars had been developed though they were neither cheap nor reliable enough to compete seriously with the horse or even the bicycle....".[2]

Similarly, from the earliest days of the internal combustion engine, the potential for adapting it to a variety of fuels has been widely perceived. For example, ethanol

> "... was used to run some of the earliest automobile engines and Henry Ford equipped some of his first models with carburetors that could be adjusted to take alcohol, gasoline, or any mixture of the two".[3]

Gasoline and ethanol blends containing up to 20 per cent

---

[1]Lester R. Brown, Christopher Flavin and Colin Norman, Running on Empty: The Future of the Automobile in an Oil Short World (New York: W. W. Norton & Company, 1979), p. 9.

[2]Ibid., pp. 8 & 9

[3]Ibid., p. 35.

ethanol were marketed in the United States as gasohol during the nineteen twenties and thirties.[4] Further, as the pace of technological development picked up during the twentieth century various other fuel possibilities were conceived and brought to various stages of development. For example, propane has been used as a vehicle fuel in countries such as Italy and the Netherlands for many years.[5]

Despite the foregoing, from the beginning of the twentieth century gasoline moved rapidly to a position of dominance in the vehicle fuel market. As well as its adequacy from handling and efficiency perspectives, gasoline remained remarkably inexpensive for the first 73 years of the twentieth century due to recurring gluts in the oil industry along with apparently unlimited quantities of easily accessible reserves. Fuel price and availability tended to result in a focus of research at the commercial level on gasoline-oriented technology. But, as noted in Chapter I, gasoline's dominance as a vehicle fuel carried with it the corollary of dependence and vulnerability.

---

[4] Ibid.

[5] Charles Slagorsky, Alternative Transportation Fuels in Canada (Calgary, Alberta: The Canadian Energy Research Institute, July, 1982), p. 12.

That it was primarily the price and availability of naturally occurring oil that slowed the commercial development of alternative fuels has been demonstrated both before and after 1973. For example, faced with curtailment of oil supplies, Nazi Germany developed a process for the manufacture of synthetic gas (SNG) from coal during World War II.[6] As a result of its perceived state of seige the Republic of South Africa has developed an extensive liquifaction capability[7] for the production of oil from coal. By 1979 one facility was in operation and a second much larger facility was expected to be on-line in the early eighties. At that point the process could be expected to supply 35 to 50 per cent of the country's petroleum requirements.[8] Following the shock of oil supply curtailment in 1973 and the rapid and significant price increases that followed, the government of Brazil

> "... launched an ambitious program in 1975 to convert part of (the country's) large sugarcane crop to ethanol. By mid-1979, Brazil was producing almost 700 million gallons of ethanol, about 14 per cent of its gasoline requirements".[9]

---

[6]Stobaugh, Robert and Daniel Yergin, eds., Energy Future: Report of the Energy Project at the Harvard Business School (New York: Random House, 1979), p. 68

[7]Ibid., p. 103

[8]Ibid

[9]Lester R. Brown et al., Running on Empty, p. 36

Further, the government stimulated the development of engines designed to burn pure ethanol. Commercial production was underway by 1981.[10] New Zealand has opted to utilize Mobil Oil's Methanol-to-Gasoline (MTG) synthesis-- "... a method of producing synthetic gasoline from methanol using natural gas as the primary feedstock"[11] -- and CNG[12] as fuel options.[13]

---

[10] British Columbia, Ministry of Energy, Mines and Petroleum Resources, Alternative Fuels for Automotive Vehicles in British Columbia (Prepared by Canadian Resourcecon Limited. Vancouver, 1981), p. 74.

[11] Canada, Special Committee on Alternative Energy and Oil Substitution, Energy Alternatives (Ottawa: Supply and Services Canada, 1981), p. 192.

[12] Slagorsky, Alternative Transportation Fuels, p. 17

[13] Although a number of alternative fuel options appear readily available, wide scale utilization should be undertaken in an orderly and balanced manner. Failure to do so can result in problem substitution rather than problem solving. For example, Brazil's use of ethanol and its reduction of oil imports has resulted in shortages of diesel fuel.

2.2 Alternative Fuels in Canada

Vehicle fuel alternatives that have been given consideration in post-1973 Canada include

- hydrogen
- synthetic gasoline and diesel
- a gasoline additive-extender derived from methanol
- blended alcohol fuels
- neat methanol
- neat ethanol
- liquified natural gas (LNG)
- compressed natural gas (CNG)
- propane

For the purpose of this study, fuel extenders, while they may be useful in reducing gasoline consumption and costs, are not regarded as alternative fuels. Further, the alcohol in the gasoline-alcohol blends will be treated as a fuel extender since the fuel is composed of 9 parts gasoline and 1 part alcohol as it is currently marketed in Canada. Thus, gasohol will not be considered as an alternative fuel in the context of this study. With these qualifications, the balance of this chapter is devoted to a brief review of the alternative fuels listed above. Among major considerations is the potential of an alternative fuel to serve as a fuel option for the University of Manitoba today or in the immediate future.

2.2.1 *Hydrogen* H_2

Hydrogen has been hailed as the fuel of the future by a small but highly vocal number of advocates. It can be used in modified internal combustion engines.

> "Public buses running on hydrogen have been successfully tested in California, Utah and Missouri ... and the Daimler-Benz Corporation of West Germany is building hydrogen buses for use in the City of West Berlin..."[14]

As a fuel hydrogen has been stored as a liquid or as a metal hydride. As a metal hydride the fuel is heavy and could only be used where weight is not a serious concern (for example, large buses).[15]

Although liquid hydrogen has over twice the energy value of gasoline by weight it has only about 25-30% of gasoline's energy value by volume.[16] Fuel tanks, particularly for smaller vehicles, could greatly reduce the space available in the vehicles and thus, in many cases, the overall usefulness of the vehicles.

Adding to the complexities and thus the handling/space/storage problems of liquid hydrogen are the facts that it must be kept at below -217° to maintain liquidity

---

[14] Slagorsky, Alternative Transportation Fuels, p. 25

[15] Canada. Energy Alternatives. pp. 198-9.

[16] Fuel comparison chart provided by D. E. Mathers of the Manitoba Research Council.

and that it has a high evaporation rate.[17] Dealing adequately with these factors would add significantly to the cost of both vehicles and fuel handling facilities for liquid hydrogen.

Based on its high volatility, hydrogen is widely regarded as a very dangerous fuel. Today, however "many scientists are prepared to argue that hydrogen is safer than most other fuels..."[18] Regardless of the possible theoretical merits of such arguments, considerable demonstration would be necessary to gain wide public acceptance of hydrogen.

Today, hydrogen is produced for use in a number of industrial processes including the refining of crude oil (hydrocracking). In the mid-1970's Wilson Clark noted that most hydrogen was produced "by reforming hydrocarbon 'feed' materials such as natural gas, propane, butane, naptha, and unused petroleum refinery gases".[19]

---

[17] Slagorsky, Alternative Transportation Fuels, pp. 23-4.

[18] Ibid., p. 23

[19] Wilson Clark, Energy for Survival: The Alternative to Extinction, Anchor Books ed. (New York: Anchor Press/Doubleday, 1975), p. 342.

As the cost of hydrocarbon 'feed' increased and its availability decreased, industries turned to other manufacturing processes - in particular, the electrolysis of water - for hydrogen.[20] "Unfortunately, most electrolytic processes are highly inefficient... (as) each energy conversion process entails significant energy losses."[21]

Considerable increases in electricity generating capacity would be necessary to produce the vast quantity of hydrogen required to accommodate significant expansion of its use. The cost of this capacity would be reflected in the price of the fuel. Although improvements in the efficiency of electrolytic processes are possible[22] and the production of hydrogen through the thermal decomposition of water using the heat from nuclear reactors is claimed to be less expensive than electrolysis,[23] it seems likely that "the high future costs of hydrogen will prohibit... (its)... use for an auto economy."[24]

---

[20]Ibid.

[21]Ibid.

[22]Ibid., p. 334.

[23]Ibid., p. 345.

[24]Ibid., p. 352

Even if the above-noted problems did not exist, there is no infrastructure in place to support a hydrogen powered transportation system.[25]

In summary, problems of technology and cost (fuel handling, storage, range), public acceptance (perceived danger) and the lack of a distribution system make hydrogen irrelevant as a replacement to gasoline in the immediate future (for example, before 1990).

2.2.2 *Synthetic Gasoline and Diesel*

While various technologies appear to be available to accomplish the production of synthetic fuel it is not currently considered commercially viable to do so in Canada. It has been estimated that these technologies could be employed in commercial scale use shortly after 1990.[26] Synthetic transport fuels derived from coal have been estimated as having an even more distant time horizon.[27] Thus, synthetic fuels do not represent an option in the immediate future.

---

[25]Canada, Energy Alternatives, p. 198.

[26]Canada, Transport Canada, An Investigation of Propane as a Motor Vehicle Fuel in Canada prepared by R. F. Webb Corporation Ltd., in association with Canadian Resourcecon Ltd., Cogesult Ltee. and Martec Ltd. (Ottawa: February, 1982), p. 19.

[27]Ibid.

2.2.3 *Neat Methanol - CH_3OH*

"Methanol ... was used as an automotive fuel in the early twentieth century and ... is still used to run some types of vehicles (for example, racing cars) ... It is especially suitable for use in high-compression engines."[28] This fuel has interesting possibilities as it can be produced from "... a range of carbon-containing substances, such as wood, wood (waste) products and municipal solid wastes ..."[29] as well as from natural gas and coal. It could thus serve as a bridge between fossil fuel dependency and reliance on a renewable resource base. While the production technology is considered currently available,[30] it "... is highly complex and similar in some respect to petroleum refining."[31]

While methanol is used for certain special-purpose automotive engines, it is not suitable for direct use in standard automobile engines as it is corrosive to certain fuel handling components. Further, it is susceptible to cold starting problems although these can be dealt with

---

[28] Lester R. Brown et al. Running on Empty, p. 39

[29] Ibid., p. 40

[30] Canada. Energy Alternatives, p. 194

[31] Lester B. Brown et al. Running on Empty, p. 40

through the use of propane or butane.[32]

Methanol burns about 25 per cent more efficiently than gasoline on a volume basis. However, because its energy content by volume is only about 48 per cent that of gasoline, fuel tanks in methanol-fueled vehicles would have to be almost twice the size of those in comparable gas-fueled vehicles in order to maintain a comparable driving range.[33]

Although the price of methanol has been considerably lower than gasoline, it has not been low enough to be cost effective when the energy content factor was taken into consideration.[34] In the Central Canadian markets of Southern Ontario the adjusted price difference was marginal during the summer of 1981. However, in Western Canada, the price of gasoline was significantly lower than the adjusted methanol price during the same period.[35] Further, the above costs do not cover the costs of vehicle conversion or methanol distribution for vehicles. Once these costs are taken into consideration, the fuel is seen to be uneconomic, even in Central Canada.[36]

---

[32]Slagorsky, Alternative Transportation Fuels, p. 6.

[33]Ibid.

[34]Ibid.

[35]Ibid.

[36]Ibid., pp. 38-9.

Engine conversion kits are not currently available in North America although the cost of conversion has been estimated at a modest $300 per vehicle.[37,38]

From an environmental perspective methanol is biodegradable and thus the potential hazard posed by fuel spills is lower for methanol than gasoline.[39] The organic emissions from methanol-fueled engines are 70 to 99 per cent alcohol rather than "true hydrocarbon species."[40] The volume of these emissions approximates the level of hydrocarbon emissions from a gasoline fueled engine. The level of carbon monoxide emissions is similar to the level produced by gasoline fueled engines. The emission levels of nitrous oxides are significantly lower than those of similar gasoline engines. The levels of aldehyde emissions are significantly higher in methanol fueled engines than in comparable gasoline engines but as with other emissions, the technology is available to reduce the emissions to low levels.[41]

---

[37]British Columbia, Alternative Fuels, p. 74

[38]Other estimates and current experience suggest that, at present, conversion costs are significantly higher than $300

[39]Canada. Energy Alternatives, p. 194

[40]Henry G, Adelman, "Methanol and Ethanol as Fuels for Spark Ignition and Diesel Engines" (Unpublished, June 20, 1980), n. pag.

[41]Ibid.

A practical limitation on the use of methanol is the fact that the current distribution network for methanol as an automotive fuel is extremely limited.

One study has estimated that methanol could be in commercial use shortly after 1990 (about 10 years).[42] Others believe methanol as a vehicle fuel could be commercially viable in a shorter time span. In the author's view methanol will not be a viable fuel option for the University of Manitoba in the immediate future.

2.2.4 *Neat Ethanol* - C_2H_5OH

Like methanol, ethanol was used as an automotive fuel early in the twentieth century. As previously noted, ethanol is currently being used on an extensive and increasing scale in Brazil although the stripping of forests to provide more sugarcane acreage has caused considerable economic dislocation.

At present ethanol is produced largely from surplus food crops (e.g., sugarcane in Brazil). Given the world food situation, the development of substantial dependence on automotive fuel from food crops raises some ethical questions that could conceivably affect widespread consumer acceptance. At a more practical

[42] Canada, An Investigation of Propane, p. 19

level, the supply of feedstocks depends on food crop surpluses. In years of poor harvests the fuel might become inordinately expensive or might be unavailable in required quantities. Present technologies for the conversion of cellulose materials such as wood, paper, pulp and municipal solid waste to ethanol are more expensive than those for the conversion of crops.[43]

As with methanol, ethanol has a corrosive effect on some fuel handling components of a standard automobile[44] (e.g., the fuel tank, fuel pump and numerous plastic parts).[45] These problems have been overcome through materials substitutions in Brazil.[46] Studies in Brazil have indicated that an engine designed to burn ethanol should cost no more than one designed to burn gasoline.[47] As noted, such engines are currently being manufactured in Brazil. Conversion of a standard gasoline burning engine to burn ethanol include

> "... carburetor adjustments, the addition of a device to improve starting, and alterations to the cylinder block to raise the compression."[48]

---

[43] Lester R. Brown et al., Running on Empty, p. 39

[44] British Columbia, Alternative Fuels, p. 74.

[45] Canada, Energy Alternatives, p. 195.

[46] Ibid.

[47] Lester R. Brown et al., Running on Empty, p. 36.

[48] Ibid.

Conversion kits are not currently available but the cost of converting a standard gasoline burning engine to accomodate the use of pure ethanol has been estimated at $300.[49] It should be noted that failure to change parts subject to corrosion could result in increased maintenance costs but the problem appears to be less acute with ethanol than with methanol.

By volume the energy content of ethanol is about 33 per cent greater than that of methanol or about 64 per cent of a similar volume of gasoline. Even allowing for the more complete combustion of alcohol fuel the size of the fuel tank would have to be increased by 33 per cent if an ethanol fueled vehicle were to maintain the driving range of a comparable gasoline fueled vehicle.[50]

At present, the cost of ethanol production is not competitive with gasoline.[51] To summarize information previously noted, ethanol production processes using less expensive feedstocks such as municipal wastes are quite expensive while the simpler and less expensive ethanol production processes require more expensive feedstocks such as food crops or sugar beets.[52]

---

[49] British Columbia, Alternative Fuels, p. 74.

[50] Ibid.

[51] Slagorsky, Alternative Transportation Fuels, pp. 8 and 40-8.

[52] Ibid.

The environmental aspects of ethanol as a power fuel are similar to those of methanol.[53]

The current distribution network for ethanol as an automotive fuel is extremely limited.

It has been estimated that ethanol, like methanol, could be in commercial use shortly after 1990.[54] It is, however, not relevant as a fuel option for use by the University of Manitoba in the immediate future.

2.2.5 *Liquified Natural Gas (LNG) - predominantly CH_4 (methane)*

Natural gas is a clean burning fuel that is abundant in Canada. In liquified form it can be burned in conventional automobile engines if they are modified appropriately. Conversion kits are available and the cost of conversion is approximately $2500.[55]

The cost of fuel alone for a vehicle run exclusively on LNG has been estimated as lower than any of its alternatives including compressed natural gas, propane and gasoline.[56] However, the high costs associated with the

---

[53] Canada, Energy Alternatives, p. 194

[54] Canada, An Investigation of Propane, p. 19

[55] British Columbia, Alternative Fuels, p. 74.

[56] Ibid., p. 62.

installation of a fuel handling facility raise the total annual costs of using this fuel significantly higher than those of other fuels.[57]

There is no distribution system in place for LNG as an automotive fuel and problems related to its handling, storage and safety would appear to preclude its public acceptance as an alternative transportation fuel in the near future.[58] It has been estimated that LNG could be commercially viable shortly after 1990.[59]

However, on balance the cost and lack of a distribution system preclude further consideration of LNG as a fuel option for the University of Manitoba in the immediate future.

2.2.6 *Compressed Natural Gas (CNG) - predominantly CH_4 (methane)*

Compressed natural gas may be used to fuel conventional automobile engines modified to accommodate the fuel. Conversion kits for CNG are available and conversion costs run from $1500.[60] to $1800.[61] This cost may be significantly reduced in the near future. The Canadian government has introduced a grant program and is expected to pass enabling legislation by mid-1983. The program will provide $500. per vehicle for businesses and institutions wishing to convert to CNG.[62]

---

[57] Ibid.

[58] Canada, Energy Alternatives, p. 192.

[59] Canada, An Investigation of Propane, p. 19

[60] British Columbia, Alternative Fuels, p. 74

[61] Interviews with Jan MacKinnon, CNG Fuel Systems Ltd., September 24 and 25, 1982.

[62] Ibid.

From an environmental perspective, engines burning natural gas produce significantly lower levels of carbon monoxide, hydrocarbon, nitrogen oxides and ethylene equivalents emissions than comparable gasoline burning vehicles.[63] Because natural gas burns more cleanly than gasoline, maintenance savings can be expected for cars fueled with CNG.[64]

As noted in subsection 2.2.5, the cost of the natural gas alone would be significantly lower than the cost of alternative fuels. However, it would be necessary to install fuel handling facilities at the University and this could be quite expensive unless a considerable number of vehicles utilizing significant quantities of fuel were converted.[65,66]

---

[63] British Columbia, Alternative Fuels, p. 7.

[64] Ibid., p. 74

[65] Ibid., p. 62.

[66] Rapid changes are occurring with respect to the availability of medium and small scale compressor technology and it was difficult to get precise figures for equipment rental. Nevertheless, based on information obtained during an interview with Jan MacKinnon of CNG Systems Ltd., Vancouver, it would appear that the minimum annual rental for a small compressor would be about $6000.

CNG Systems Ltd. of Vancouver is expected to expand to Winnipeg before mid-1983 and thus facilities for conversion and servicing of vehicles should be available in the near future.[67]

Perhaps the greatest technological weakness associated with the use of CNG as a fuel for general use vehicles is the limited range of CNG fueled vehicles. The range is said to be between 100[68] and 240[69] kilometers--significantly less than a comparable gasoline fueled vehicle.

Currently, an embryonic CNG distribution system is in place in Vancouver, Calgary and Toronto but no facilities exist in Winnipeg. While the Winnipeg situation may change in the near future, the distribution system is likely to be quite limited for at least a couple of years.

To summarize, natural gas may be available in Winnipeg within a year. The costs associated with a central fueling facility might require the conversion of a considerable percentage of University vehicles to keep the costs competitive with gasoline. The off-campus

---

[67]Interview with Jan MacKinnon, CNG Fuel Systems Ltd., September 24 and 25, 1982.

[68]British Columbia, Alternative Fuels, p. 74.

[69]Interview with Jan MacKinnon.

availability of the fuel is likely to be quite limited. Since about 41 per cent of the volume of fuel purchases related to University vehicles during a year are made from off-campus filling stations (see subsection 1.7) the vehicle use pattern would seem to preclude the conversion of certain vehicles to CNG. Based on the current available information, the potential of CNG as a fuel option for the University of Manitoba should probably be reevaluated about 1985.

2.2.7 *Propane - C_3H_8*

Like natural gas, propane may be used to fuel conventional automobile engines modified for that purpose. Indeed, as noted in Section 2.1, propane has been used as a vehicle fuel in Holland for over 25 years. In recent years its use in North America has been increasing steadily. In Canada, conversions to propane have increased spectacularly since the initiation of the Canadian Government's propane conversion program in October, 1980. For example, it was estimated that 13,000 vehicles were utilizing propane by March, 1982, as compared to a few hundred prior to the fall of 1980.[70]

---

[70]Ontario, Ministry of Transportation and Communication and Ministry of Energy, Drive Propane: Preliminary Summary of Fleet Demonstration Results. (Toronto: Ontario Government, March 1982), n. pag.

Conversion kits are available for propane and the cost of conversion starts at about $1500. if installed by a firm selling propane carburetion services. Grants of up to $400. that are available to businesses and institutions such as the University of Manitoba through the Canadian Government's Propane Vehicle Grant Program can reduce the net cost to about $1100 plus tax (calculated on the gross price).[71]

Like natural gas, propane burns more cleanly than gasoline and this finds financial expression in lower engine maintenance costs.[72]

The current price of propane is significantly lower than the price of gasoline even after allowing for propane's lower energy content per unit of volume.

It would be necessary to install fuel handling facilities at the University of Manitoba. These could be obtained at an annual rental of $600.[73] The annual rental of $600 for fuel handling facilities would mean that an overall economic gain could result from the

---

[71] Interview with representative of CIGAS PRODUCTS LTD., Winnipeg, January, 1982

[72] British Columbia. Alternative Fuels, p. 74.

[73] Interview with representative of CIGAS PRODUCTS LTD., Winnipeg, September 23, 1982.

commitment of a much smaller percentage of the fleet than would be the case for natural gas.

In response to the increase in propane fueled vehicles, the distribution system has matured rapidly although it does not approach the availability offered by the gasoline distribution system. An example of the change in the distribution system is provided by the Manitoba situation. In Manitoba, the number of retail propane outlets for automotive fuel increased from 10 in 1980 to at least 36 in 1981.[74] By Mid-September, 1982, Winnipeg had 24 hour availability of propane for automobiles from 2 retail outlets (The Propane Shack, 660 Nairn Avenue and Headingly Husky).

The brief initial review suggests that propane could serve as an economically viable fuel option for the University of Manitoba.

2.3 Summary and Conclusions

This chapter has reviewed a number of potential automobile fuels that have received varying degrees of attention following the curtailment of oil supplies in

---

[74] Canada. An Investigation of Propane, pp. 86 & 86a.

1973 and the subsequent increases in the price of oil.

While a few of these alternatives show future promise, only compressed gas and propane appear as viable fuel alternatives in the immediate future.

As a vehicle fuel, compressed natural gas is not yet available in Winnipeg. Further, certain costs would appear to require the commitment of a large percentage of the University fleet to natural gas in order to achieve economic viability. But preliminary review of the University's pattern of vehicle activity, based on its purchases of fuel, suggests that such a commitment is not warranted given an almost non-existent commercial distribution system for natural gas as an automotive fuel.

Propane, on the other hand, appeared promising as an immediate fuel option. In terms of its current price, fuel cost savings appear possible. The low cost associated with a central fuel facility at the University offers the possibility of experimenting through the conversion of a limited number of vehicles on an economically viable basis. The current depth of the commercial propane distribution system suggests that certain University vehicles used extensively off campus could be considered as potential candidates for conversion along with vehicles used primarily in the campus area.

While this preliminary review has produced the conclusion that propane is currently the most promising of potential alternative fuel options, a considerably more detailed examination of all aspects of the propane option is necessary before recommending its use. Such an in-depth review is presented in Chapter III.

CHAPTER III

PROPANE IN DETAIL

3.1 Introduction

As an integral element in the evaluation of propane's potential as a viable fuel alternative, this chapter presents a review of relevant aspects of the fuel and its related carburetion technology from a decision-making perspective.

3.2 The Nature of Propane

Propane -- C_3H_8 - is a short-chain hydrocarbon of the paraffin series found in association with crude oil and natural gas deposits. While under pressure in deposit sites, it will be in a liquid or gaseous form depending on whether the temperature in the deposit is less than or greater than the critical temperature of propane[1] -- 96.7° C.[2] The greater the depth of the deposit, the greater its temperature[3] and

---

[1]The critical temperature is the temperature above which a gas cannot be liquified by pressure alone. Under high pressure, the gas would become very dense and liquid-like. In such circumstances, it would be referred to as a plasma.

[2]Karl L. Yaws, Physical Properties: A Guide to the Physical, Thermodynamic and Transport Property Data of Industrially Important Chemical Compounds (New York: McGraw-Hill, 1977), p. 88.

[3]The temperature underground may be determined through the use of the following formula:

$$\text{Temperature } ^\circ F = 35^\circ + \frac{18.5 \times \text{depth in feet}}{1000}$$

Information provided by Mr. D. Exall, Petro Canada Manager of Production Applications Research during an interview in February, 1983.

propane in deposits deeper than about 2800 metres could be expected to be gaseous. (Currently, the depth of the average hydrocarbon well in Alberta is between 1524 and 2438 metres.)[4] Under reduced pressure as it is released from the deposit, the propane evaporates or maintains its liquid form.[5] At atmospheric pressure, however, its normal state is gaseous as its boiling point is -42°C.[6]

It is a suitable fuel for internal combustion engines equipped to handle it. The energy content of the fuel is 25.53×10^6 joules per litre or about 74 per cent of the energy content of an equal volume of gasoline. While propane has a lower heat value by volume than gasoline, its combustion is more complete by 10 to 15 per cent.[7]

Liquid propane usually contains small quantities of other hydrocarbons. Government regulation requires that for use in a motor vehicle, the liquid must be at least 90 per cent propane and can contain no more than five per cent propylene. Other hydrocarbons such as butane may make up the remaining five per cent. This mixture is known as

---

[4]Data in feet provided by Mr. D. Exall, Petro Canada Manager of Production Applications Research during an interview in February, 1983.

[5]Canada, Energy Alternatives, p. 192

[6]Canada, Federal Propane Vehicle Program Newsletter, (n.p.: n.p.), n. pag.

[7]Ibid.

Grade I propane or HD-5. It constitutes the bulk of propane available in Canada.[8] In its Standard Specification for Liquid Petroleum Gases the American Society for Testing and Materials states that some standardization of the composition of propane used as a vehicle fuel is required "to meet the restrictive needs of internal combustion engines operating under moderate to high engine severity."[9] (The standardization of composition produces a fuel with less variable combustion characteristics).

Propane's ignition temperature in air is 468°C while that of gasoline is 222°C. It has a higher octane rating (110) than gasoline (82 to 100) and is thus less susceptible to spontaneous combustion.[10]

3.2.1 *Extraction of Propane*

To prevent condensation during long-range transmission, "substantial quantities" of the light hydrocarbons heavier than methane such as the pentanes, butanes and propane must be removed from natural gas.[11] Collectively these lighter hydrocarbons are known as natural gas liquids (NGL). It

---

[8] Ibid.

[9] The American Society for Testing and Materials, American National Standard, (3 pages of microfilm printout obtained from Manitoba Research Council), pp. 133-5.

[10] British Columbia, Alternative Fuels, p. 4.

[11] Canada, An Investigation of Propane, p. 20.

should be noted, however, that

> the gas processors maintain that the high proportion (80%) of gas liquids extraction is voluntary, only 20% of the gas liquids removal being (required) to meet pipeline transmission specifications.[12]

In Canada, NGL are stripped from natural gas at about 100 field plants in British Columbia, Alberta and Saskatchewan.[13] At 34 of these plants there are 'fractionating' facilities for the separation of the NGL into its constituents -- propane, butanes and pentanes.[14] In addition, there are six gas reprocessing or "straddle" plants,[15] that employ cryogenic processing -- a technique that achieves separation through a combination of pressure and temperatures below -50°F.[16] -- which remove further quantities of propane from the natural gas.

Propane is also manufactured from crude oil

> ...as either a by-product or prime product in processes where higher carbons are cracked to lighter ones -- particularly in the presence of hydrogen (hydrocracking processes).[17]

Should certain synthetic fuel projects get underway, propane would be produced as a co-product from either tar sands

---

[12]Ibid., p. 59

[13]Ibid., p. 23

[14]Ibid.

[15]Ibid.

[16]Petroleum Extension Service, Fundamentals of Petroleum. 2nd ed. (Austin, Texas: University of Texas, 1981). pp. 218-220.

[17]Canada, An Investigation of Propane, p.

bitumen or coal.[18]

To Summarize, propane is produced whenever petroleum is refined to produce gasoline and other petroleum products or natural gas is 'stripped' to transport it to market. Thus, although there would appear to be room for variation, a supply of propane is produced irrespective of propane demand.

As propane is a hydrocarbon its production will ultimately dwindle as crude oil and natural gas reserves are depleted. This being the case, propane can hardly be considered as a permanent automotive fuel alternative to gasoline. Indeed, one might question why propane is considered an alternative to gasoline at all. The answer to this question lies in an analysis of the supply of and demand for propane.

3.3 Supply and Demand

3.3.1 *International (Excluding Canada)*

Prior to the increases in the world prices of crude oil and natural gas that began in 1973, much of the rich oil-well gas associated with the production of oil

---

[18] Ibid., p. 21

was simply burned off or flared.[19, 20]

> With the advent of (these higher prices)..., the oil producing nations embarked upon an aggressive program to recover and market LPG...[21]

As a result of this program, world export availability of propane is expected to increase from a 1980 level of 25 x 10^6 m^3 in 1980 to 68 million m^3 by 1985.[22] This would result, by 1985, in a propane surplus of 38 to 40 x 10^6 m^3 in excess of present consumption.[23] In addition, during the immediate future propane penetration of relevant markets currently serviced by gasoline will be slowed by the present oil glut.

3.3.2 *Canada*

"The quantity of natural propane in reserves in Canada (has been) estimated by the National Energy Board at some 63 x 10^6 m^3."[24] It should be noted, however, that this figure excludes the potential supply that would be produced as a co-product if tar sands bitumen and coal were processed to produce liquid fuels.[25]

---

[19] Ibid., p. 37

[20] In fact, a number of oil producing countries continue the practice of flaring the gas. (For example, Mexico and Libya continue to flare natural gas in 1983.)

[21] Canada, An Investigation of Propane, p. 37.

[22] Ibid.

[23] Ibid.

[24] Ibid.

[25] Ibid.

During the six-year period from 1975 through 1980, gross propane production in Canada averaged about 7000 x 10^3 m^3 per year of which about 80 per cent was produced by natural gas plants and 20 per cent by oil refineries.[26] During the same period, domestic demand averaged no more than about 45 per cent of production.[27] These figures, based on a review of actual data and forecasts for 1981, are assumed to represent the current situation with respect to Canadian propane production and sales.[28] Of domestic sales by volume, almost 71 per cent of the propane is used for furnace burning applications in the residential, commercial and industrial sectors while about 16.5 per cent is used in the petrochemical industry and less than one per cent is used as a transport fuel.[29] Almost 11 per cent of current gross propane production is

---

[26] A variety of sources were examined. None of the production figures were in precise agreement as various <u>unspecified</u> elements were included or omitted. The figures presented in this paper represent 'ballpark' approximations that were set around the mid-point of the source figures reviewed. The particular sources reviewed were as follows:

1) Canada, <u>An Investigation of Propane</u>, pp. 22, 38, 36 and 81.
2) Canada, National Energy Board. <u>Canadian Energy: Supply and Demand</u>, 1980 - 2000. (Ottawa: Supply and Services Canada, 1981), pp. 184, 220, 299-302.
3) Canada, Energy, Mines and Resources, <u>Energy Statistics Handbook</u>. (Ottawa: Energy, Mines and Resources, March, 1982). p. 330.

[27] Ibid.

[28] Ibid.

[29] Canada, <u>An Investigation of Propane</u>, pp. 80 - 2.

committed to long-term licensed contracts not subject to NEB approval.[30]

From a regional perspective, the Prairie Provinces currently produce almost 87 per cent of total Canadian supplies.[31] On the other hand, Prairie demand represents less than 20 per cent of the region's production (see Appendix B and Table III).

With respect to local supply, propane is produced at one refinery.[32] However, production of that refinery could not amount to more than about half of Manitoba's current annual requirements.[33] In the author's view, this local supply/demand situation is not relevant in assessing security of supply. Review of the Prairie supply/demand balances adequately covers certain considerations with respect to security of local supply. Other aspects will be covered during review of the distribution system.

Tables I and II are presented as a basis for discussion concerning future supply/demand balances at the national and regional levels. Each table contains two supply forecasts.

---

[30] Ibid.

[31] Ibid., p. 38.

[32] Canada, Transport Canada, Potential Propane Vehicle Fuel Market: Ontario, Manitoba, Saskatchewan, Alberta and British Columbia, 1980 - 1990. (Prepared by Canadian Resourcecon Limited). (Vancouver: n.p., 1980), p. 3.

[33] Ibid. See also Appendix B.

TABLE I

PROPANE SUPPLY/DEMAND BALANCES

CANADA

(10^3 m^3)

Year	Supply		Demand
	NEB Base Level	Incentive Level	
1981	7,464	n.a.	3,420
1985	7,957	8,213	3,835
1990	5,913	6,935	6,189
1995	5,402	7,300	7,106
2000	5,110	8,030	7,196

Sources: Supply - Canada, An Investigation of Propane, p. 38
Demand - Canada, N.E.B., Canadian Energy, p. 220

TABLE II

PROPANE SUPPLY/DEMAND BALANCES

PRAIRIES

(10^3 m^3)

Year	Supply		Demand
	NEB Base Level	Incentive Level	
1981	6,466	n.a.	1,258
1985	6,909	7,128	1,367
1990	4,833	5,800	3,316
1995	4,289	6,074	4,780
2000	3,896	6,543	4,744

Sources: See Table I and Appendix B.

The forecasts labelled "NEB Base Level" are based on a "conserve-the-resource" approach to natural gas and assume that natural gas use will be restricted, the rate of discoveries and additions to reserves will decline, and that no stimulative measures will be taken to increase conventional recovery. Further, these forecasts exclude frontier gas from supply. The base level forecast assumes modest increases in refinery production at least until the year 2000. This is based on expected throughput which is related to projected demand for refined petroleum products. No pricing incentives are assumed and this results in the continued use of propane within refineries. Potential supply of synthetic propane produced as a co-product of synthetic fuels is also excluded from the 'base level' forecasts.[34]

The forecasts labelled "Incentive Level" assume a more abundant perceived reserve situation with respect to natural gas accompanied by attempts to stimulate the use of natural gas as part of the Canadian Government's oil substitution program as well as the expansion of gas exports. This forecast also assumes the continued development of gas reprocessing plants ("Straddle" plants) as well as the development of gas supplies from frontier sources such as Sable Island (the Sable Island deposits are expected to have a

---

[34]Ibid. See also Appendix A.

relatively high LPG content). In this forecast, pricing incentives are also assumed to stimulate propane recovery from certain gas plants as well as the marketing of propane currently produced and consumed within the refineries. Finally, the "Incentive Level" forecast assumes the recovery of significant quantities of propane from tar sands, heavy oil, synthetic gas liquids and coal processing operations.[35] (Propane from these sources is forecast to provide about five per cent of total supply by 1990, nine per cent by 1995 and 15.5 per cent by 2000).[36]

It should be noted that recent 'conventional' natural gas discoveries have had a lower LPG content than earlier discoveries. Accordingly, based on the assumption that refining activity will increase moderately, the percentage of total propane supply derived from gas plants is expected to decline from about 81 per cent in 1981 to about 69 per cent or 58 per cent in the Base and Incentive Level forecasts respectively.[37]

The demand forecasts are drawn from the NEB's 'middle case' demand projections. These projections are based on

---

[35] Ibid.

[36] Ibid., p. 36

[37] Ibid.

assumed growth rates in real GNP that vary between three and 3.6 per cent over the period 1980 to 2000.[38]

If the NEB Base Level supply and middle case demand situations develop, Canada will experience supply shortages by 1990 and the Prairies by 1995. If the Incentive Level supply and middle case demand situations develop, no shortages will occur in the country or the region before 2000.

3.3.3 *Comments and Conclusion*

In the author's view, the NEB Base Level supply situation is unlikely to develop. The implementation of the National Energy Program and the Alberta/Canada energy agreement is involving aggressive attempts to expand domestic use of natural gas as a substitute for oil as well as the support of export sales. During the past two years, conventional reserves have been expanded through announced discoveries and this lends credibility to the effort to substitute gas for oil. On the other hand, the current world glut has resulted in the shelving of certain synthetic fuel projects such as Alsands. Thus, it seems likely that the levels of synthetic propane production projected in the Incentive Level supply forecast are also unlikely to be realized. Further, the current oil glut is likely to act

---

[38]Canada, Canadian Energy, p. 20

at least temporarily as a retardant on frontier development.

The current economic situation, which involves considerably less than a three per cent growth rate, could depress propane demand below the levels used in the NEB middle demand forecast. The expansion of the natural gas pipeline network can be expected to lower the demand for propane as a heating fuel. As a final point, the uncontrolled status of propane prices could be a factor that operates to slow growth in demand for propane.

Lower demand would, in turn, affect the supply of propane supply adversely. Certainly discretionary production of propane would decline and refinery-utilized propane would not find its way to market.

On balance, it is the author's view that actual supply will fall between the levels in the forecasts presented in Tables I and II. It seems unlikely that supply shortages will occur at either the national or regional level before 2000. Any shortages that do occur are likely to be the result of production planning and allocation problems and, as such, are likely to be temporary. For several years following 1985 it seems likely that such temporary shortages could be 'covered off' at reasonable cost due to the large increase in the world supply of propane that will occur in the mid-1980s.

In the short and medium term, propane supply considerations should not be considered a constraint on the utilization of propane as a motor vehicle fuel.

3.4 Distribution of Propane

3.4.1 *Primary Distribution*

A complex and specialized system involving pipeline, rail and highway modes has developed in Western and Central Canada for the bulk movement of LPGs.[39] Based on current and historical production and demand patterns, the present distribution system is "...geared to gas plant product, export and domestic heating markets."[40] The seasonal nature of the current major source of demand for propane (for example, for space heating) makes very large bulk storage for long periods an essential feature of propane's primary distribution .[41]

The Petroleum Transmission Pipeline (PTP) is used to move propane directly from a straddle plant at Empress, Alberta, to Winnipeg (Fort Whyte) which is a major centre for underground and surface storage. These facilities

---

[39]Canada, Potential Propane Vehicle Fuel Market, p.4.

[40]Canada, An Investigation of Propane, p. 40.

[41]Ibid., p. 41.

serve as a base for rail shipments to the north central United States and to northern and western Ontario.[42] Further, an unmanned pipeline "truck key stop" enabling local distributors to buy propane from the line and auxiliary storage tanks -- is located in Rapid City, Manitoba.[43]

Despite the movement of high volumes of propane by pipeline to certain storage and redistribution points, the bulk of the product movement is by rail

> ...in shipper or consignee owned or leased cars -- the Canadian railways do not generally supply LPG tank cars.[44]

It is the city's connection to a pipeline and its location as a rail centre, both of which operate as links between the producers and the wider market they need for their product, that provide Manitoba, in general, and Winnipeg, in particular, with security of supply within the surplus-laden Prairie region.

3.4.2 *Secondary Distributors*

Unlike the oil producers, most refiners and producers of propane from natural gas "...do not participate in the

---

[42] Ibid., p. 43

[43] Canada, <u>Potential Propane Vehicle Fuel Market</u>, p. 8

[44] Ibid., p. 9

propane enterprise in an integrated fashion."[45] Rather, they sell their product through bulk distributors (wholesalers).

In western Canada, the development of the propane market

> ... has led to the trucking of bulk propane by road to rural customers with one or more 1000 gallon tanks and to commercial and industrial users with ... above ground tank storage...[46]

As noted in Section 2.2.7, the number of propane retail outlets for automotive fuel in Manitoba increased from 10 in 1980 to at least 36 in 1981. Similar increases occurred in the other Prairie provinces and in Southern Ontario. Winnipeg has 24 hour availability at the retail level.

3.4.3 *Comment and Conclusion*

As with gasoline, bulk fuel handling facilities would be necessary at the University if a decision is made to utilize the propane fuel option. As suggested, the current distribution system is adequate to handle this aspect of the University's requirements.

---

[45] Canada, An Investigation of Propane, p. 45.

[46] Ibid., p. 47

In the author's view, the retail distribution system is mature enough to consider propane conversion for vehicles used extensively off-campus. The viability of such conversions would have to be made on a case by case basis, depending on the particular use patterns of specific vehicles.

3.5 The Price of Propane

The relationship of propane to gasoline prices is the key determinant of the economic viability of propane conversion.

In general, the price of propane will be affected by the price of the natural gas and oil from which it is extracted. Based on the sources of Canadian propane, and an existing propane surplus, natural gas prices can be expected to have the more significant effect.

Transportation and storage costs can constitute up to 30 per cent of the pump price.[47] This factor, together with varying royalties and taxes and distributor margins causes considerable variation in the price of propane throughout the country and even at various points within the province.

---

[47] Canada, An Investigation of Propane, p. 68

The current price of propane compares favourably with gasoline and this situation is expected to continue. On June 9, 1981, J. Erola, Minister of State, speaking on behalf of Energy Minister, Marc Lalonde, stated that

> The Canadian government is committed to a significant increase in the use of propane in domestic markets, to displace oil. Having made this commitment, it is our intention that propane prices will become increasingly competitive with the price of oil products in areas where propane already has a price advantage (for example, Western Canada).

Further, in correspondence with the author dated November 10, 1981, a representative of the Winnipeg branch of EMR's Conservation and Renewable Energy Branch stated that,

> Our best estimate for propane would be that the predicted cost increase would generally be pegged at two-thirds the price of gasoline.[48]

It should be noted that at present, the price of propane is not regulated and if that situation is to continue, the maintenance of such a ratio would depend on general supply/ demand conditions and the provision of tax and other incentives by the various levels of government.

Review of future price prospects by Manitoba Telephone System personnel indicated that a significant price differential should continue to exist at least until the

---

[48]W.J. Bryant, Canadian government's Conservation and Renewable Energy Branch of Energy, Mines and Resources. Letter. November 10, 1981.

mid-1990's.[49]

With respect to Manitoba road tax, the amount of the tax is set at 20 per cent of the pump price of regular gasoline net of the road tax prevailing at the time the tax is determined. Although the tax is specified as a percentage of pump price, it is fixed in amount based on periodic reviews made by the relevant department of the Manitoba Government.[50] For tax purposes, the price of propane is set at 60 per cent of the price of gasoline. The tax is then set at 20 per cent of the deemed price of propane with the qualification that the minimum has been set at four cents per liter.[51] In short, the Manitoba road tax on propane has been set at 60 per cent of the road tax on gasoline. The tax thus operates to increase the monetary spread between the prices of gasoline and propane. In terms of percentages, the tax increases the spread if the propane price exceeds 60 per cent of the gasoline price and decreases the spread if propane is less than 60 per cent of the price of gasoline.

---

[49] R.J. Blomquist, Fleet Control Administrator, Manitoba Telephone System. Interview. August, 1982.

[50] Manitoba Statutes, Chapter G40, An Act to Provide for the Imposition of a Tax on Purchasers and Users of Gasoline, (December, 1980), Sec.3(1), 3(1.1) and 3(1.2).

[51] Manitoba Statutes, An Act to Provide for the Imposition of a Tax on Purchasers and Users of Motive Fuel, (December, 1981), Sec. 3(1) and 3(13).

Prior to mid-September, 1982, the price of automotive propane in Winnipeg was about 60 per cent of the price of an equal volume of gasoline. A price increase in mid-September 1982, raised the relative price of propane to over 65 per cent of the price paid by the University for gasoline. More specific and detailed consideration of gasoline-propane price differences is provided in Chapter IV.

Although the recent price increase would definitely affect the economics of conversion to propane, ultimate viability would depend on the maintenance of the current difference or an increase in the future price difference and the details of the case under consideration.

For the purposes of this analysis, it will be assumed that the Canadian government will, if necessary, take action to ensure that the price of propane does not exceed two-thirds of the cost of gasoline during the 1980's. If this is accomplished, the monetary price difference between the prices of propane and gasoline will increase as the prices of the two products rise.

3.6 Propane Carburetion Technology

3.6.1 *Basic Description*[52]

Any propane carburetion system consists of the following component groups:

---

[52]Canada, Department of Energy, Mines and Resources, Propane Vehicles: Economical and Safe. n.p.: n.p., n.d., pp. 4-7.

1. A pressurized fuel tank

2. A fuel-lock and filter -- The fuel lock releases the propane from the fuel tank to the vapourizer only when the engine is operating or being started. It operates through an ignition solenoid or an engine vacuum-control signal.

3. A vapourizer-pressure regulator system -- The vapourizer changes the propane from a liquid to a gas by passing it through a heat exchanger and pressure reducer. It provides propane gas to the regulator which reduces the gas pressure and supplies it to the carburetor. The regulator also serves as a safety shut-off valve.

4. An air-propane gas carburetor -- This may be accomplished by the installation of a carburetor designed specifically for propane or through the purchase of an adaptor for an existing carburetor.

The configuration of a propane vehicle fuel system is presented in Figure 3.1 while a comparison of gasoline and propane carburetion is presented in Figure 3.2.

As well as the parts substitution, conversion to propane involves minor engine adjustments relating primarily to the choice of spark plugs, which should "be gapped closer in a propane engine to give a hotter, more reliable spark", the installation of a lower temperature thermostat (ideally about 160° F or 57°C and no more than 180°F or 68°C),[53, 54]

---

[53] Ontario, Ministry of Transportation and Communication and Ministry of Energy, Switching to Propane: A Guide for Fleet Operators (Toronto: Ontario Government, August, 1981), p.21.

[54] For use in Manitoba winters, vehicles should be equipped with a secondary thermostat that maintains a temperature of 190° F or about 74°C in order to provide adequate heat to the passenger compartment.

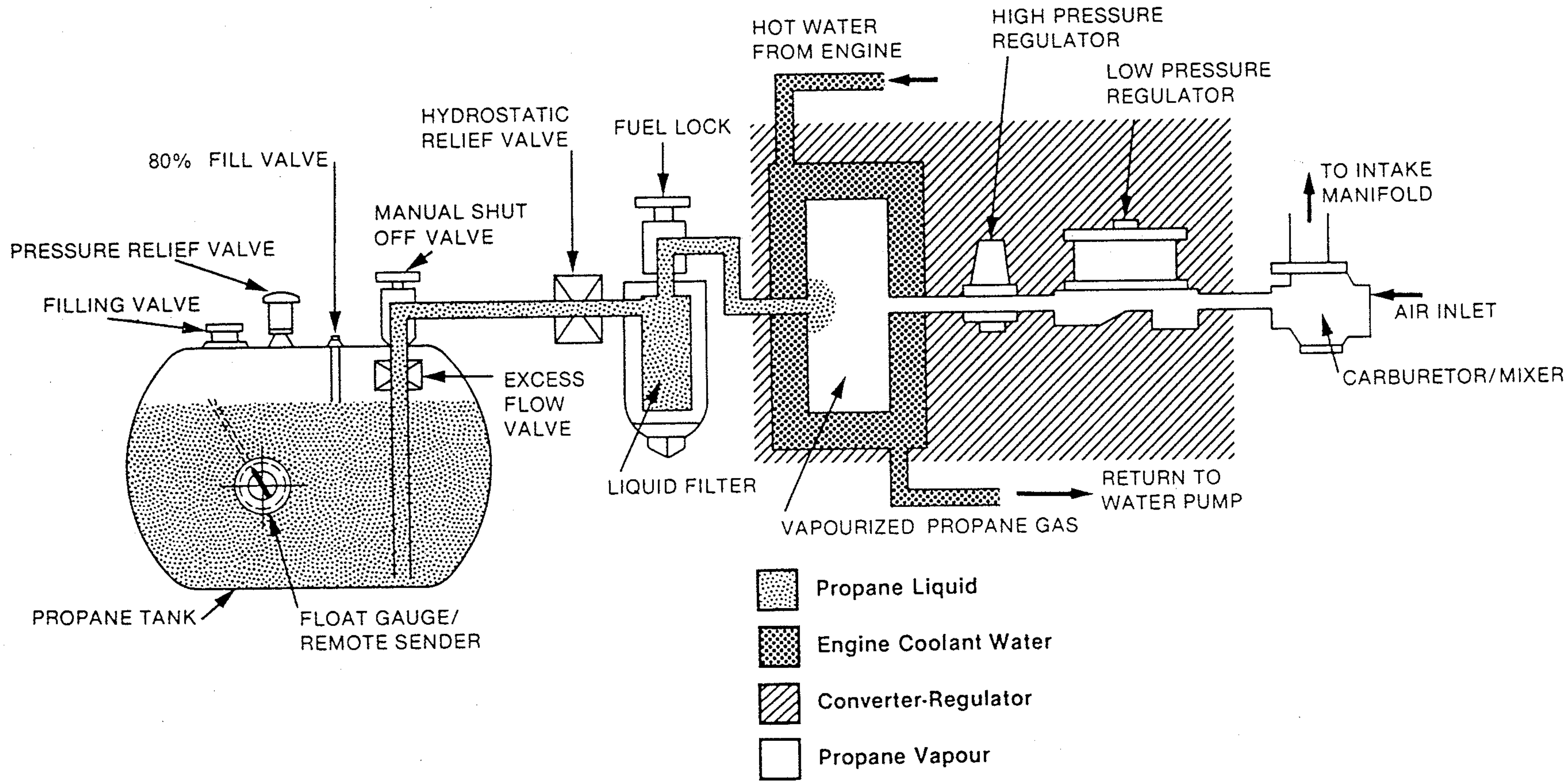

Figure 3.1: **Propane fuel system.**

Source: Canada, Department of Energy, Mines and Resources, <u>Propane Vehicles: Economical and Safe</u>, p. 5.

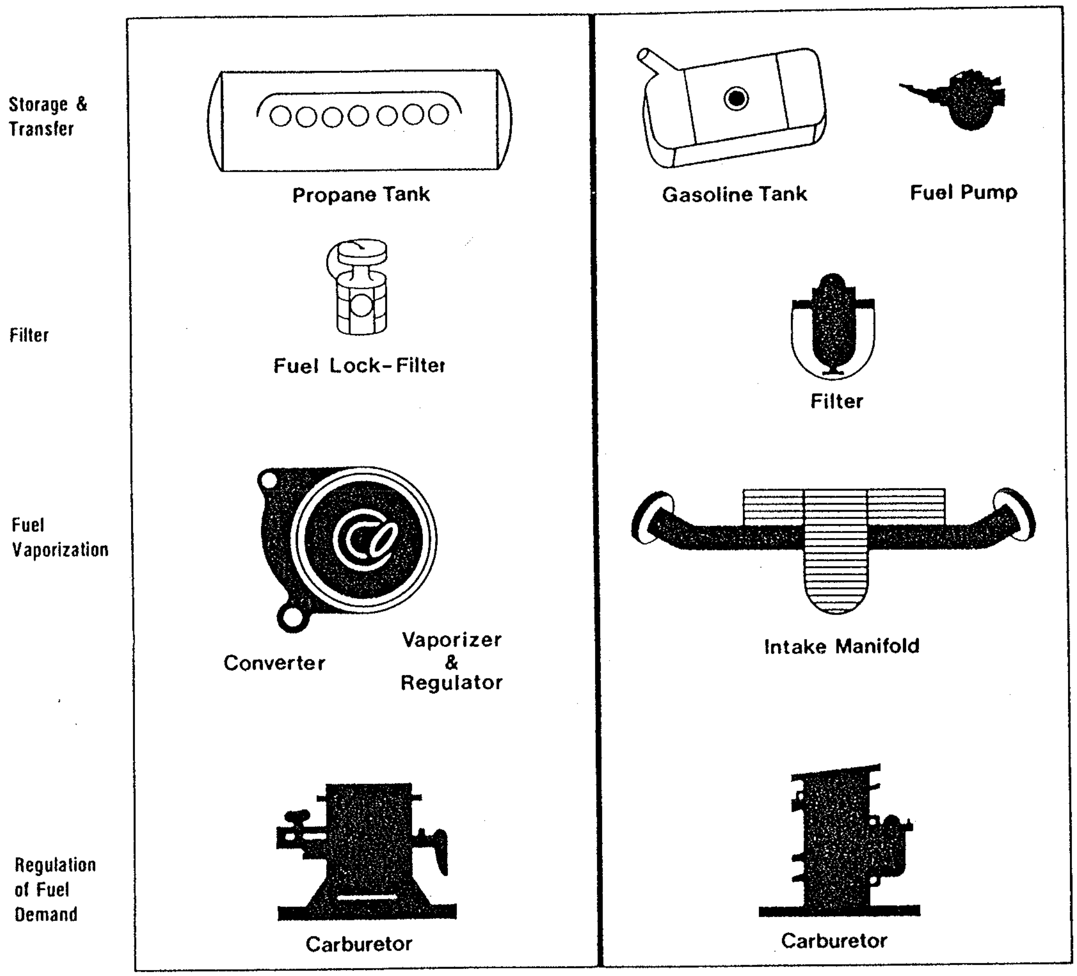

Figure 3.2: **Comparison of propane and gasoline fuel systems.**

Source: Canada, Department of Energy, Mines and Resources, Propane Vehicles: Economical and Safe, p. 6.

and adjustment of the compression ratio from 8:1 to 11:1 to prevent a loss of power.[55]

In Winnipeg, a number of firms offer installation and maintenance services. As well, at least one firm (CIGAS) undertakes the training of the customer's mechanics.

Currently, a limited number of the vehicles equipped to burn propane are being produced directly at the factory. For example, the Ford Motor Company offers factory-produced propane-burning vehicles as an option with at least one of its vehicles.

3.6.2 *Cost of Conversion*

In Winnipeg a survey of two organizations performing installations suggested that the cost of conversion for a vehicle the size of an econoline van or smaller would range from $1,200. to $1,500. plus tax. This would include a fuel tank with a capacity of 20 to 25 gallons. Larger vehicles or larger fuel tanks would cost more.[56] One study of the cost of alternative fuels use listed the cost as $1,200.[57] R.J. Blomquist of the Manitoba Telephone System

---

[55]British Columbia, Alternative Fuels, p. 24

[56]Representatives of CIGAS and Metro Propane, Interview, November, 1981.

[57]British Columbia, Alternative Fuels, p. 74.

suggested that about $150. per conversion could be saved once an organization's mechanics had been trained to perform them.[58]

Because propane burns 'hotter' than gasoline certain vehicles designed for regular leaded gasoline may burn out the valves and valve guides when the vehicle is converted to propane. The cost of replacement with hardened valve seats should not exceed $200.[59] Valve seat replacement at the time an engine was being rebuilt would add virtually nothing to the cost. This problem would appear to be largely theoretical. The Manitoba Telephone System has been operating converted vehicles for over a year and a half and the problem has not occurred.[60]

3.6.3 *Performance*

As previously noted, propane has an energy content that is about 75 per cent of the energy content of gasoline while propane combustion is 10 to 15 per cent more complete than that of gasoline. A commonly accepted fuel displacement figure is 1.2 where 1.2 liters of propane is assumed

---

[58] R.J. Blomquist, Interview

[59] Ibid.

[60] Ibid.

to displace one liter of gasoline.[61] This figure is compatible with the results obtained in fleet demonstrations in Ontario[62] and will be accepted in this study for analytical purposes. It should be noted, however, that certain extreme test situations -- for example, operation of the vehicle at very high engine speeds -- have produced displacement factors of 1.4 to one in even the best system.[63]

Generally, propane fueled vehicles idle and accelerate more smoothly than comparable gasoline fueled vehicles.[64]

Concern has been expressed about propane's starting potential in extremely cold conditions. Indeed, in a test performed in Manitoba, a propane fueled engine could not be started at a temperature of -38°C[65] although in a second trial using a new battery apparently -42°C emerged as the point at which the vehicle would not start. This matter

---

[61]British Columbia, Alternative Fuels, p. 74.

[62]Ontario, Ministry of Transportation and Ministry of Energy. Drive Propane: Preliminary Summary of Fleet Demonstration Results, (n.p.: n.p., March, 1982), n. pag.

[63]Ontario, Ministry of Transportation and Communications. Testing and Evaluation of Automotive Propane Conversion Equipment. Prepared by L. Segal, Department of Mechanical Engineering, University of Toronto, (Toronto: Ontario Government. February, 1982), p. 82.

[64]Ontario, Preliminary Results, n. pag.

[65]Canada, Department of Energy, Mines and Resources, Low Temperature Starting Characteristics of Propane Fueled Automobile Engines. Project No. W-81-004-FI. Prepared by R.P. Shand, P. Eng. (Manitoba: Industrial Research Centre/ Manitoba Research Council, February, 1982), p. 1.

could be of some concern since Winnipeg experiences temperatures of that extreme during its winters. (Statistically, these extremes are infrequent but there is a risk between November and April).[66] Review of the test conditions indicated that they were extreme and would unlikely be encountered in real operating conditions (for example, the time length of the 'cold soak' and the complete absence of sunlight).[67] Further, operating experience obtained by the Manitoba Telephone System as far north as Flin Flon, Manitoba, revealed no particular problems with starting propane fueled vehicles under severe conditions.[68] The MTS experience was confirmed by the preliminary results of the Ontario Fleet Demonstration Program which noted that "...starting was generally no more a problem with a propane fuel system than with gasoline."[69] Based on the field results, it is the view of the author that the starting of propane fueled vehicles in cold weather should not be considered a problem in evaluating the propane fuel alternative.

---

[66] Representative of the Canadian Government's Climate Services, Interview, September, 1982.

[67] D.E. Mathers, Manitoba Research Council, Interview, September, 1982. Also, R.J. Blomquist, Interview, September 1983.

[68] R.J. Blomquist, Interview, September, 1982.

[69] Ontario, Preliminary Results, n. pag.

Problems with the performance of propane motor vehicle fuel systems include inaccurate propane fuel gauges, lack of heat and the noxious odor of the fuel. The heating problem, originally caused by the new thermostats installed during conversion to propane, has been solved by changing thermostats a second time. The odor of propane is caused by a substance added to the fuel as a safety precaution.[70]

3.6.4 *The Safety of Propane Motor Vehicle Fuel Systems*

With respect to safety, propane engine fuel has had an excellent safety record during its many years of use in Europe. Recently, the Research Institute for Road Vehicles TNO of Delft, the Netherlands, conducted a series of grueling and spectacular crash tests with both stationary and moving objects and concluded propane is safer than gasoline as a motor fuel. The test results appeared to support the theory that most accidents are due to improper installation of fuel tanks by non-professional, unqualified individuals.[71] In terms of safety under operating conditions, two propane fueled police cruisers in Windsor, Ontario were involved in accidents in which they were struck and damaged in the area

---

[70] Ibid.

[71] "Propane Proved Safe as a Motor Fuel", Butane-Propane News, July, 1980, pp. 26-33 and "Both Front and Rear LPG Systems Can Take It", Butane-Propane News, December, 1980, pp. 23-25.

of the propane tank. In neither case did the tank, piping or valving suffer any damage.[72]

Apart from their sturdy construction, propane fuel tanks are equipped with a number of safety features designed to

> ...prevent fuel spillage or excessive pressure build-up within the container. These include a double non-return filler valve, pressure relief and atmospheric vent line...

as well as an automatic 80 per cent 'stop-fill' valve.[73]

Safety conditions are thus considered adequate for propane motor vehicle technology.

3.6.5 *Environmental Considerations*

Because, relative to gasoline, the combustion of propane is more complete, it is generally a cleaner burning fuel than gasoline. Tests using three vehicles by different manufacturers produced the following results with respect to average exhaust emissions:

Carbon Monoxide - propane produced emissions 84 per cent below the level produced by gasoline.

Hydrocarbons - propane produced emissions 49 per cent below the level produced by gasoline.

Nitrogen Oxides - propane emissions were 56 per cent below the level produced by gasoline.

Aldehydes - both fuels produced the same level of emissions.

Reactivity, Ethylene Equivalents - propane emissions were 26 per cent below the level produced by gasoline.

---

[72] Ontario, Preliminary Results, n. pag.

[73] Canada, Economical and Safe, p. 4.

These tests were performed under conditions utilizing the manufacturers' recommended adjustments. Further, engines were optimized for balanced emissions and performance.[74] In other tests in which the gasoline engine had an emission control device while the propane engine did not, propane registered higher emission levels except for carbon monoxide.[75]

These results suggest that propane fueled engines should be operated with emission control devices whether or not they are required to do so. Under equal operating conditions, propane would appear to be environmentally preferable to gasoline.

3.6.6 *Maintenance*

Because propane is a relatively clean and sulfur free fuel and because its efficiency of combustion is greater than that of gasoline

> reduced maintenance, longer engine life and reduced vehicle downtime are among the major benefits of propane conversion.[76]

In particular, propane

> does not tend to corrode valves, piston rings, pistons and cylinders to the extent the sulfur and lead-containing gasolines do.[77]

---

[74]British Columbia, Alternative Fuels, p. 7

[75]Ontario, Testing and Evaluation, p. 82

[76]British Columbia, Alternative Fuels, p. 26

[77]Ibid.

and this causes somewhat less wear on engines. Further, because of the gaseous state of propane, there is no dilution of the lubrication oil through condensation as occurs with gasoline. As a result, "...oil consumption is reduced to between a third and a half of that by a similar gasoline engine."[78]

On the negative side, the presence of lead "seems to result in a longer valve life (than would otherwise be possible)."[79]

Despite general agreement in the literature and 'on the street' that genuine maintenance cost savings are associated with propane carburetion, the specifics are difficult to obtain. One factor is the lack of control vehicles run on identical duty cycles. A second problem is the difficulty and cost of accumulating data in a way that enables precise identification of savings, particularly where this has not historically been done.

> A rough justification of the maintenance cost saving is that at 75,000 miles (about 121,000 kilometres) a propane engine will not have required major engine work while a gasoline engine will likely have been rebuilt at a cost of $700 - $900.[80]

---

[78] Ibid.

[79] Ibid.

[80] Ibid.

In one study of alternative fuels, a value of five cents per gallon or 1.1¢ per liter of gasoline equivalent has been assigned to maintenance cost saving. This is based on the discount offered by an independent service organization for the service work performed on fleet vehicles fueled by propane.[81]

3.7 Other Equipment

As indicated in Section 2.2.7, utilizing the propane motor vehicle fuel option at the University of Manitoba would require the installation of bulk fuel handling facilities on the campus. (This would also be true of many commercial fleet situations).

Basically, the equipment required includes a pump, a meter and a bulk storage tank. These can be either purchased or rented as part of a fuel purchase contract.

The price to purchase a tank would be between $4,500. and $5,000.[82]

Annual rental costs of the equipment were determined in November, 1981, and late September, 1982. These are listed below:[83]

---

[81]Ibid.

[82]Representatives of Superior Propane, Metro Propane and CIGAS, telephone inquiries, November, 1981, and September, 1982.

[83]Ibid.

Supplier	November, 1981	Late September, 1982
A	$ 250.	$ 600.
B	$ 480.	$ 600.
C	--	$ 708.

Regardless of whether a tank is purchased or rented, the installation of bulk storage and fuel handling facilities requires site preparations. Site preparation includes the enclosure of the facility with a six foot chain link fence, the installation of explosion-proof electrical wiring for the pump, and the preparation of a 'Hard Top' surface on which to locate the tank.[84]

The experience of the Manitoba Telephone System suggests that these costs should not exceed $1200. per site.[85]

Installation charges for the tank have been quoted as being $250.[86]

3.8 Other Considerations

3.8.1 *Introduction of a Technology*

Often the way in which a technology is introduced to an organization can determine the 'success' or 'failure'

---

[84]Representatives of Metro Propane and CIGAS and R.J. Blomquist, Fleet Control Administrator, Manitoba Telephone System, Interviews, November, 1981.

[85]R.J. Blomquist, Interview, November, 1981.

[86]Representatives of propane distributors, Interviews, November, 1981.

of the technology within the organization. Introduction of a technology in an autocratic or threatening manner often creates resistance on the part of those who will be working directly with it. This resistance can and often does deprive the organization of benefits it might otherwise have obtained through the use of the technology.

With respect to the utilization of the propane option, a number of information sessions should be held with employees who would be affected from both an administrative and operating perspective. Questions should be encouraged and suggestions sought. The approach should, in short, be non-threatening.

Discussions with both dealers and users have convinced the author that attitudes throughout the potential user organizations are of critical importance.

3.8.2 *Administrative Considerations*

The introduction of any new technology requires administrative and accounting adjustments. It is important that these matters be given consideration in advance of the actual undertaking. Failure to do so would make it difficult if not impossible to evaluate performance.

3.9 Concluding Remarks

This chapter has presented a review of propane supply, price and technology. In general, supply was considered adequate for both the short and intermediate term, the prospects of a continuing relative price advantage for propane vis-a-vis gasoline appeared reasonable, and propane technology was reviewed and found to be effective, serviceable and moderately priced. In addition, certain non-economic aspects of technological change were given brief consideration.

This could be called a general review. In the following chapter, information outlined during the general review is selectively integrated with information specific to the University of Manitoba to demonstrate an approach to evaluating the viability of the propane motor vehicle fuel option.

CHAPTER IV

EVALUATING THE VIABILITY OF PROPANE CONVERSION

4.1 Introduction

Using selected data related to the University of Manitoba, this chapter presents and demonstrates a methodology for evaluating the economic viability of propane as a vehicle fuel at the University.

In this particular evaluation, the factors affecting economic viability are the costs associated with conversion, the maintenance savings associated with the use of propane, the current and future propane/gasoline price differential, the useful lives of the vehicles chosen for conversion, and the period over which the analysis is performed. Potential conversion of diesel engines has been excluded from the analysis. Technological problems of diesel conversion to propane make its consideration impractical at the time of this study.[1] Its elimination in no way affects the validity of the methodology as it could be integrated into the

[1] R. J. Blomquist, Discussion, April, 1983.

analysis if the technological problems were overcome and the required information was readily available.

The chapter concludes with a review of certain institutional characteristics of the University and a discussion of their potential significance for a propane conversion project.

4.2 Methodological Considerations

4.2.1 *Introduction*

In this study the analytical approach used to assess economic viability centres on the determination of the volume of displaced gasoline that would be required to cover the costs of propane conversion (the break-even volume) and the use of this information to determine the net gains or losses from conversion that would be produced over time.

4.2.2 *Data Requirements and Assumptions - Current Costs*

To utilize the methodology presented in this study the following information must be assembled:

1. The current price(s) that the organization under study is paying for gasoline must be determined. This information should be readily accessible through a review of the organization's records and supporting documentation.

2. The current price of propane must be ascertained. This information can be obtained from local suppliers.

3. The current costs associated with propane conversion must be assembled. This information should be obtained through inquiries directed to both potential suppliers and selected current users where possible.

4. The annual fuel consumption of each gasoline fueled vehicle in the organization's fleet must be determined. Any organization in which adequate management control over resources is exercised should be able to determine, without undue effort, the annual fuel consumption of each vehicle in its fleet.

In addition, assumptions must be made with respect to the following:

1. The relative energy content by volume of the two fuels must be assigned a value. (This will be referred to as the relative energy content factor). The theoretical comparative energy content by volume of different fuels may be obtained from various easily accessible sources. However, practical experience is generally at variance with the theoretical value due to such factors as varying completeness of combustion and ultimately the acceptance of a value represents an assumption (See 3.6.3).

2. Maintenance cost differences associated with the use of propane and gasoline must be estimated. Because hard data on maintenance cost savings is somewhat thin at the time of this analysis, an assumed value will have to be utilized. Despite the lack of hard data, it is the author's view that enough information is available to allow the development of a credible estimated value (See 3.6.6).

3. The future behavior of propane and gasoline prices, maintenance costs, and fuel consumption patterns must be estimated. In this presentation it is assumed that all three factors remain constant throughout the period of the analysis. With respect to the future propane/gasoline price differential the assumption is based on the review of propane supply

and stated government policy as outlined in Chapter III. With respect to fuel consumption patterns, it is reasonable to assume, in the absence of evidence to the contrary, that actual established consumption patterns will continue. The assumption regarding future maintenance cost savings is the most arbitrary assumption simply because the figure used for current savings is not based on an abundance of hard data. It is, however, considered adequate for the purpose of this study.

4. The useful lives of the vehicles must be estimated. As noted in section 1.7, the vehicle replacement policy that appears to be in practice at the University of Manitoba can best be described as "running the vehicles into the ground." Depreciation is not systematically recorded. The task of estimating the remaining useful lives of potential conversion candidate vehicles should be performed by those responsible for managing and maintaining the vehicles. In practice, the task has not been performed and for the purposes of this study values will simply be assumed

5. The time period covered by the analysis should be a management decision. Again, for the purposes of this study a value will be assumed.

The integration of the above factors into an economic analysis is presented in the following section.

4.2.3 *Methodology and Rationale*

Once the relevant data has been gathered and required assumptions have been made, the first step in the evaluation involves the determination of the monetary saving that would result from the displacement of a unit of gasoline at a given point in time. This is accomplished through the performance of the following procedures.

1. The unit price(s) of propane is (are) multiplied by the relative energy content factor to yield the cost of the volume of propane required to displace a unit of gasoline.

2. The price(s) of the energy equivalent volume of propane determined in (1) above is (are) deducted from the organization's current unit price(s) of gasoline to produce the fuel price saving(s) associated with a unit of gasoline displaced by propane.

3. Maintenance cost savings per unit of gasoline displaced are then added to the value(s)determined in (2) above to produce the total saving(s) per unit of fuel displaced that would be produced by substituting propane for gasoline as a vehicle fuel.

Note: Propane can be substituted for either leaded or unleaded gasoline. Further, in Manitoba propane and gasoline prices vary by the amount of the provincial road tax on fuel depending on whether the vehicle is used for farm or non-farm purposes. The calculations outlined in points (1) to (3) above should be performed for each relevant pricing situation.

The second step in the analysis involves the determination of the break-even volumes of gasoline that must be displaced to cover the various costs associated with converting vehicles and facilities to the use of propane. Total rather than annualized volumes are determined because this approach provides more flexibility in the early stages of the analysis.

Costs expressed in terms of displacement volumes are calculated by dividing the various monetary costs associated with propane conversion by the saving(s) per unit of gasoline displaced as calculated above. It should be noted that

a. the calculation must be performed for each cost element rather than some derived overall total cost figure, and

b. a set of calculations should be performed for each monetary saving per unit of gasoline displaced figure derived earlier in the analysis.

At this point it is convenient to set up a break-even worksheet, particularly if the analysis involves more than one fuel-type (e.g., use of regular and unleaded gasolines, farm and non-farm use, involves four fuel types and prices. Thus, four monetary savings per unit of gasoline displaced figures will have been determined in the early stages of the analysis). The worksheet may be organized by using columns for cost type identification, cost description, monetary cost and each fuel type. Rows are used for each cost element. At the top of each fuel type column, the monetary saving per unit of volume of fuel displaced should be recorded. In each fuel type column, on the same row as each cost element will be the break-even displacement volume of that fuel type for that cost element.

In this study, costs are identified as site costs--associated with the preparation and maintenance of central fueling facilities on the organization's premises--and vehicle-specific costs. Site costs must be recovered from the gasoline displacement savings produced by the propane fleet as a whole while vehicle-specific costs must be recovered from the gasoline displacement savings of the vehicle(s) to which they apply.

Site costs are classified as either operating or capital costs. Operating costs are further classified as either annual or intermittent costs. Annual costs such as the yearly bulk propane tank rental charge must be recovered each year. Intermittent costs such as a bulk tank installation charge should be recovered over the period of the initial propane supply contract. (If, at the end of the initial contract, the propane supplier is changed, the charge might be incurred again).

The period over which either site or vehicle-specific capital costs should be recovered is a matter for management decision. Such a decision would likely take into account such factors as the expected life of the project, the estimated useful lives of the proposed propane-fueled vehicles, and the highly changeable conditions in the fuel markets.

Once the displacement volumes of the vehicle-specific conversion costs and the expected recovery period of vehicle-specific costs have been determined, the information, together with the annual gasoline consumption figures of the organization's potential conversion candidate vehicles, can be used to perform a preliminary screening of the vehicles.

To accomplish this, each vehicle's gasoline consumption over the expected recovery period is determined by multiplying the vehicle's annual consumption by the number of years in the expected recovery period and comparing the result to the relevant vehicle-specific cost(s). Only if a vehicle's consumption equalled or exceeded its vehicle-specific cost(s) would it be considered potentially suitable for conversion.

When potential vehicles for conversion have been selected and a project period has been established the net benefits or costs of the project can be determined on either a total or annual basis. If the net benefits are to be calculated on a total basis, annual costs and benefits (in terms of volumes of gasoline displaced) must be determined for the total project period. If the net benefits are to be calculated on an annual basis, capital and intermittent costs must be converted to annual charges by dividing the total costs by the number of years in the project period.

In the author's view, presentation of capital costs on an annual basis in this type of analysis is misleading and should be avoided. The fact is that the capital costs must be paid at the beginning of the project period while the benefits as defined above will be received throughout the project. (This fact will be addressed in Section 4.2.4). Presentation of all costs and benefits on an annual basis could imply that net benefits will occur annually. In fact, costs will be paid and then recovered after which benefits will be received. If, for some reason, the project had to be ended prematurely, benefits calculated on the entire project period could be reduced or eliminated. The fact that an 'annuallized' net benefit may have been recorded at the end of one or more years would be meaningless. Average net benefits could be calculated from an overall net project evaluation. In the author's view, this would be a more satisfactory approach than implying, through a series of specific calculations, that net benefits would be received in each year of the project.

In the simplest case where vehicles to be converted burn the same fuel (e.g. regular gasoline: non-farm use) costs and benefits are calculated as follows:

1. All costs and benefits are adjusted to the same lapsed-time basis.
2. Relevant vehicle-specific costs are multiplied by the number of vehicles to be converted to propane.

3. The total in step (2) is added to the other cost elements.

4. Benefits are calculated as the total gasoline consumption of the vehicles to be converted.

5. Net benefits or costs are determined by deducting costs [(Step 3.)] from benefits [(Step 4.)].

6. Net monetary benefits are then calculated by multiplying the net benefits in units of gasoline displaced [(Step 5.)] by the monetary benefit per unit of gasoline displaced.

If the vehicles to be converted burn two or more types of fuel (e.g., regular and unleaded gasoline: nonfarm use), the costs and benefits are calculated as outlined below:

1. As in the simplest case all costs and benefits are adjusted to the same lapsed-time basis.

2. Relevant vehicle-specific costs for each fuel type are multiplied by the number of vehicles using that fuel type.

3. The displacement volumes for each site cost element are determined as follows:

   a. The ratio of a fuel type's consumption to total consumption is multiplied by the break-even displacement volume for that fuel-type. This calculation is performed for each relevant fuel type.

   b. The total break-even displacement volume for a cost element is obtained by adding the amounts determined for each fuel type in Step (a) above.

4. The totals in Steps (2) and (3) are added together to produce a total cost fugure.

5. Again, benefits are calculated as the total gasoline consumption of the vehicles to be converted.

6. Net benefits or costs are determined by deducting costs [(Step 4.)] from benefits [(Step 5.)].

7. Net monetary benefits are then calculated as follows:

    a. The ratio of a fuel type's consumption to total consumption is multiplied by the net benefits in units of gasoline displaced [(Step 6.)] and the product is multiplied by the monetary benefit per unit of gasoline displaced for that fuel type. These calculations are performed for each relevant fuel type.

    b. The total net monetary benefits for the project are determined by adding the benefits related to each fuel type as calculated in Step a. above.

The analysis above will provide

1. information required to select potential candidate vehicles for conversion to propane;

2. an assessment of economic viability; and

3. the information necessary to determine the project's payback period,

under specified conditions relating to price, consumption and the length of the project.

4.2.4 *Time and Money*

As noted in Section 4.2.3, the outlays and benefits associated with a project will occur at different points in time. Even if inflation is disregarded, it is generally accepted that the value of a monetary unit in the future is less than its value in the present.

Monetary values of different time periods can be equated through the use of a discount factor expressed as a percentage. Commonly used rates include the cost of project funds, an organization's overall weighted cost of capital and an expected rate of return.

The analysis outlined in Section 4.2.3 could easily be modified to accommodate a discount factor. This could be done as follows:

1. The timing of each outlay and benefit would be identified.
2. Using a pre-selected discount rate and standard interest rate/present value tables the present value of all outlays and benefits would be calculated.

If the present value of benefits exceeded the present value of costs, the project would be considered economically viable.

Alternatively, standard interest rate tables could be used to determine the project's time adjusted rate of return. This could be compared against the expected rates of return of other projects to determine project acceptability.

4.3 A Case Study: The University of Manitoba

4.3.1 *Stage I - Conversion Costs as Displacement Volumes*

4.3.1.1 The Price of Gasoline

The University's operations involve the consumption of both regular and unleaded gasoline. Some of the fuel consumed involves agricultural uses and is exempt from the Provincial Road Tax. (It has been named 'purple' fuel after the dye that was used to identify it and control its use). Provincial tax was set at 5.7 cents per litre in November, 1981, and 6.2 cents per litre in September, 1982.[2]

The University purchases gasoline on contract and is exempt from the 1.5 cents per litre Federal Excise Tax otherwise applicable to the price of gasoline. It receives a discount of 1.9 cents per litre on gasoline purchases. The net costs of gasoline to the University at November, 1981, and September, 1982, are presented in Table III.

4.3.1.2 The Price of Propane

The prices of propane available to bulk customers are presented in Table IV. Propane used for agricultural purposes is also exempt from the Provincial Road Tax. The fuel displacement factor is assumed to be 1.2:1 (See Section 3.6.3). Based on discussion with users and personal experience with a commercial propane-fueled vehicle, the author believes this assumption acceptable but conservative. Propane prices adjusted for the fuel displacement factor are presented in Table V.

---

[2]Discussions with oil company distributor in November, 1981, and September, 1982.

4.3.1.3 Maintenance Cost Savings

Maintenance cost savings associated with propane gas are assumed to be 1.1 cents per litre of gasoline displaced. (For further details see Section 3.6.6).

4.3.1.4 Net Savings per Litre Displaced

Net savings per litre of gasoline displaced are presented in Table VI.

4.3.1.5 A Note on Vehicle Conversion Costs

With respect to vehicle conversion costs, the University is eligible for the Federal Government conversion grant of $400. per vehicle. The net cost of conversion for a university vehicle is thus assumed to be:

List price plus tax	$ 1,575.
Less: conversion grant	(400)
	$ 1,175

For further discussion see Section 3.6.2.

TABLE III

University of Manitoba Unit Gasoline Costs (Net)

¢/l

Type of Gasoline	November, 1981	September, 1982
Regular	33.0	38.4
Purple Regular	27.3	32.2
Unleaded	34.8	40.2
Purple Unleaded	29.1	34.2

Source: Invoice prices paid by the University during the relevant time periods. (See Section 4.3.1.1.)

TABLE IV

Bulk Propane Prices (Net)

¢/l

	November, 1981	September, 1982
Regular	22.5	25.2
Purple	18.5	21.2

Source: Survey of bulk propane dealers in the Winnipeg area during the relevant time periods. (see Section 4.3.1.2)

TABLE V

Bulk Propane Prices Adjusted for the Fuel Displacement Factor

¢/l

	November, 1981	September, 1982
Regular	27.0	30.2
Purple	22.2	25.4

Notes: 1. A displacement factor of 1.2 liters of propane per liter of gasoline has been assumed. (See Section 3.6.3).

Based on a number of interviews and personal experience in the commercial operation of a propane fueled vehicle, it is the author's view that, on balance, this is a conservative assumption and that any potential savings calculated from its use would not overstate the situation.

2. The figures in Table V were derived by multiplying the Table IV prices by a displacement factor of 1.2.

TABLE VI

Net Savings per Liter of Gasoline Displaced
¢/l

	Regular	Purple Regular	Unleaded	Purple Unleaded
November, 1981				
Net Price of Gasoline (1)	33.0	27.3	34.8	29.1
Less: Adjusted Propane Price (2)	(27.0)	(22.2)	(27.0)	(22.2)
	6.0	5.1	7.8	6.9
Add: Propane Maintenance Cost Savings (3)	1.1	1.1	1.1	1.1
Saving per liter	7.1	6.2	8.9	8.0
September, 1982				
Net Price of Gasoline (1)	38.4	32.2	40.2	34.2
Less: Adjusted Propane Price (2)	(30.2)	(25.4)	(30.2)	(25.2)
	8.2	7.8	10.0	9.0
Add: Propane Maintenance Cost Savings (3)	1.1	1.1	1.1	1.1
Saving per liter	9.3	8.9	11.1	10.1

Notes:
(1) Obtained from Table III
(2) Obtained from Table V
(3) Based on discount offered by independent service organization for servicing propane vehicles. (see Section 3.6.6).

4.3.1.6 A Note on Propane Bulk Storage

Given the moderate rental cost, the purchase of a storage tank would, in the author's view, be extremely wasteful.

The disadvantage of renting a bulk tank would lie in the fact that it would tie the University's fuel purchases to the supplier from which the bulk tank was rented. This could theoretically create problems in terms of the University purchasing policy. However, such problems could be overcome through the periodic opening of the contract to competitive bidding. The winning bid would be given a 'monopoly' supply position for a specific period. In such circumstances, renting a tank would be feasible.

In the author's view, renting of a bulk storage tank is the preferred option for reasons related to both cost and tank maintenance. Thus, the rental option will be assumed in the break-even analysis developed in the following sections. For further discussion see Section 3.7.

4.3.1.7 The Break-Even Worksheets

Using price and cost data presented in Chapter III and Sections 4.3.1.1 to 4.3.1.6, the break-even displacement volumes of the various types of gasoline used by the University have been calculated for each conversion cost element in terms of prevailing conditions in November, 1981, and September, 1982. The displacement volumes were calculated by dividing the various costs associated with propane conversion by the savings per liter of gasoline displaced as derived in Table VI. These break-even displacement volumes are presented in Tables VII and VIII.

4.3.2 *Stage II - Viability Calculations*

4.3.2.1 Specific Assumptions

1. In September, 1982, the University is able to reach an exclusive 5-year supply contract with a supplier who has also agreed to provide a propane bulk storage tank at a campus facility for an installation fee of $250 and an annual rental charge of $600.

2. For demonstration purposes, the following partial list of University vehicles is utilized in this study:

	Vehicle		Annual Consumption of Gasoline -liters-
a.	Garbage truck	- 1973	12,300
b.	3/4 ton truck	- 1981	6,500
c.	Van	- 1973	2,175
d.	1 ton truck	- 1981	5,500
e.	Van	- 1978	5,200
f.	Car	- 1974	2,050
g.	Van	- 1976	4,800

It is assumed that-- Vehicles a., c., f., and g. would require Valve Seat Replacement.

TABLE VII

BREAK-EVEN WORKSHEET: COSTS AS DISPLACEMENT VOLUMES

November, 1981

Cost Type	COST Description	Amount		GASOLINE Regular	Regular Purple	Unleaded	Unleaded Purple
			Saving per Liter[1]	$ .071	$ .062	$ .089	$ .080
SITE COSTS:				*BREAK-EVEN DISPLACEMENT VOLUME (liters)*			
Operating (Annual)	Tank rental[2]	480		6,761	7,742	5,393	6,000
Operating (Annual)	Tank rental[2]	250		3,521	4,032	2,809	3,125
Operating (Intermittant)	Tank installation[3]	250		3,521	4,032	2,809	3,125
Capital	Site preparation[4]	1,200		16,901	19,355	13,483	15,000
VEHICLE SPECIFIC COSTS:							
Direct Capital	Vehicle Conversion[5]	1,175		16,549	18,952	13,202	14,688
Potential	Valve Seat Replacement[6]	200		2,817	3,226	N/A	N/A

Sources:
[1] Table VI
[2] Sections 3.7 and 4.3.1.6
[3] Section 3.7
[4] Section 3.7
[5] Sections 3.6.2 and 4.3.1.5
[6] Section 3.6.2

TABLE VIII

BREAK-EVEN WORKSHEET: COSTS AS DISPLACEMENT VOLUMES

September, 1982

COST				GASOLINE			
Cost Type	Description	Amount		Regular	Regular Purple	Unleaded	Unleaded Purple
			Savings per liter[1]	$ .093	$ .089	$ .111	$ .101
				BREAK-EVEN DISPLACEMENT VOLUME (liters)			
SITE COSTS:							
Operating (annual)	Tank Rental[2]	600		6,451	6,741	5,405	5,941
Operating (intermittent)	Tank Installation[3]	250		2,688	2,809	2,252	2,475
Capital	Site Preparation[4]	1,200		12,903	13,483	10,811	11,881
VEHICLE SPECIFIC COSTS:							
Direct Capital	Vehicle Conversion[5]	1,175		12,634	13,202	10,586	11,634
Potential	Valve Seat Replacement[6]	200		2,151	2,247	N/A	N/A

[1] Table VI
[2] Sections 3.7 and 4.3.1.6
[3] Section 3.7
[4] Section 3.7
[5] Sections 3.6.2 and 4.3.1.5
[6] Section 3.6.2

- Vehicles (b) and (d) burn unleaded gasoline while the remainder burn regular gasoline
- All vehicles are estimated to have remaining useful lives of 5 years.
- The consumption patterns of all vehicles are expected to remain constant for the next 5 years.

3. Management has decided to finance the project out of its Operating Funds and to regard the project as experimental. Thus, it expects all outlays to be recovered within the initial 5 year pricing agreement.

4. It is estimated that the savings per liter of gasoline displaced as calculated in September, 1982, will at least be maintained during the 5 year project period.

4.3.2.2 Preliminary Screening

As indicated in Table VIII, the gasoline displacement volumes necessary to cover the vehicle-specific conversion costs are as follows:

1. 12,634 liters - a non-farm vehicle that burns regular gasoline
2. 14,785 liters - a non-farm vehicle requiring valve seat replacement
3. 10,586 liters - a non-farm vehicle that burns unleaded gasoline

For the 5 year period, consumption of the vehicles under initial consideration would be estimated to be:

Vehicle	Consumption for 5 years - liters -
a.	61,500
b.	32,500
c.	10,875
d.	27,500
e.	26,000
f.	10,250
g.	24,000

Based on this information it is apparent that vehicles c. and f. should not be converted to propane. Thus, the balance of the analysis will be concerned with vehicles a., b., d., e., and g.

4.3.2.3 Consumption of Selected Vehicles

The current and expected consumption of the selected vehicles is presented in Table IX. (These figures represent the project benefits in terms of volumes of gasoline displaced).

4.3.2.4 Conversion Costs in Terms of Displacement Volumes

Information from Table VIII is used to determine, in terms of gasoline displacement volumes, the conversion costs associated with the 5 year project period. The relevant calculations are presented as follows:

TABLE IX

GASOLINE CONSUMPTION OF SELECTED VEHICLES

Vehicle	Annual Consumption (liters) Regular	Unleaded	Grand Total	Expected 5-year consumption (liters) Regular	Unleaded	Grand Total
a.	12,300			61,500		
b.		6,500			32,500	
d.		5,500			27,500	
e.	5,200			26,000		
g.	4,800			24,000		
TOTAL	22,300	12,000	34,300	111,500	60,000	171,500

1. Tank Rental (5 years)

a. $\frac{12,000}{34,300} \times 5405 \times 5 = 9,455$ liters

b. $\frac{22,300}{34,300} \times 6451 \times 5 = 20,970$ liters

TOTAL = 30,425 liters

2. Tank Installation:

a. $\frac{12,000}{34,300} \times 2252 = 788$ liters

b. $\frac{22,300}{34,300} \times 2688 = 1,748$ liters

TOTAL 2,536 liters

3. Site Preparation:

a. $\frac{12,000}{34,300} \times 10,811 = 3,782$ liters

b. $\frac{22,300}{34,300} \times 12,903 = 8,389$ liters

TOTAL 12,171 liters

4. Vehicle Conversion Modifications:

a. 2 x 10,586 = 21,172 liters

b. 3 x 12,634 = 37,902 liters

TOTAL 59,074 liters

5. Valve Seat Replacement:

2 x 2,151 = 4,302 liters

Thus, in terms of the volume of gasoline that must be displaced to cover them, the total of all costs for the entire period is 108,508 liters.

4.3.2.5 Net Benefits of the Project

In terms of the volume of gasoline displaced, the net benefits of the project may be calculated as follows:

Benefits (Table IX)	- 171,500 liters
Costs (Section 4.3.2.4)	- 108,508 liters
Net Benefits	62,992 liters

The Monetary value of these benefits may be calculated as follows:

a. $\frac{12,000}{34,300} \times 62,992 \times \$.111 = \$2,446.$

b. $\frac{22,300}{34,300} \times 62,992 \times \$.093 = \$3,809$

$\$6,255$

Based on a current dollar evaluation the project would thus be considered economically viable. The payback period including the tank rental charge for the entire project would be about 38 months (108,508/34,300= 3.16).[3] Further, comparison of data presented in

[3]The project payback can also be presented in terms of distance travelled. If, for example, the vehicles averaged 10 miles per gallon (i.e. used 28.25 liters of gasoline per 100 kilometers), the payback distance would be 76,820 kilometers $(\frac{108,508}{28.25} \times \frac{100}{5})$ or 47,736 miles.

Tables VII and VIII demonstrates that the economics of propane conversion at the University of Manitoba improved between November, 1981, and September, 1982.

4.3.2.6 Adjustment for the Time/Money Factor

The University of Manitoba receives the bulk of its funding through annual grants from various levels of government. Thus, from the University's perspective, there is no direct financing cost associated with the investment of funds in particular projects.

Nevertheless, a time adjusted analysis might be considered necessary to allow the ranking of various potential projects with different cost/benefit patterns. Accordingly, the time/money factor is taken into account through the analysis presented below.

For the purposes of this section of the analysis, it is assumed that all the capital costs and the site installation costs will have to be paid at the beginning of the project period (Time 0). The annual rental costs and the benefits are assumed to be paid and received evenly throughout the year and are thus fixed at the mid-point of each year for valuation purposes. Each year is divided into two periods and time adjustment rates are applied to periods rather than years. Again the analysis is performed in terms of displacement volumes of gasoline. Annual benefits are represented by the gasoline displacement volumes presented in Table IX while the costs are derived from the cost calculations in Section 4.3.2.4. This time-cost-benefit information is presented in Table X.

The application of present value tables[2] to the time and cost information in Table X indicates that the break-even discount rate for this project is about 14 per cent per period or almost 30 per cent per year. Project acceptability would depend on the rates of the alternative projects against which it is being ranked and the availability of funds.

4.3.2.7 Conversion Costs - A Note on Sensitivity

While the conversion cost per vehicle of $1175. would appear realistic for 4 of the 5 vehicles in the case study, it is, in the author's opinion, likely that the conversion of the garbage truck would be somewhat more expensive. If the University's outlay to convert the garbage truck was $2,000., the break-even displacement volume of its displacement cost would increase by 8,871 liters over the value shown in Table VIII. The displacement volume net benefits of the project would be

---

[2] C. G. Edge, A Practical Manual on the Appraisal of Capital Expenditure, Revised Edition (Hamilton: The Society of Industrial Accountants of Canada, 16th printing), pp. 171-5.

TABLE X

COSTS, BENEFITS AND TIME

INITIAL COSTS		Annual Gasoline Displacement	Annual Rental Charge	Net Annual Benefits	Time of Occurrence	
Type	Amount	---------- *LITERS*	---------		Year	Period
Site Preparation	12,171					
Tank Installation	2,536					
Vehicle Conversion Modifications	59,074					
Valve Seat Replacement	4,302					
	78,083				-0-	-0-
		34,300	6,085	28,215	.5	1
					1.0	2
		34,300	6,085	28,215	1.5	3
					2.0	4
		34,300	6,085	28,215	2.5	5
					3.0	6
		34,300	6,085	28,215	3.5	7
					4.0	8
		34,300	6,085	28,215	4.5	9
					5.0	10

reduced to 54,121 liters but the project would still be economically viable. In such a case, the break-even discount rate of the project would fall to about 11 per cent per period or 23 per cent per year.

4.3.2.8 A Note on Financing

Theoretically, if the University financed all or some of the capital expenditure aspects of conversion from its Capital Funds or obtained extraneous funding for such capital items, about 80 per cent of all gasoline displaced would represent a reduction in its operating expenditures. However, the current state of the economy is not conducive to extraneous funding and the University is in a situation of such severe constraints that the use of capital funds for a project of this nature is extremely unlikely. For this reason, the 'bookkeeping' capital funding financial option has not been given detailed consideration. Thus, this study has presented only a full economic evaluation in which total cost recovery is mandatory if conversion is to be considered economically viable.

4.4 Potential Non-Economic Benefits

Because the technology is established, there are a minimum of technological risks associated with the use of propane as a vehicle fuel. Conversion of some of the

University vehicles to propane, would provide its personnel with experience in the introduction and administration of a different energy technology. Such experience could prove valuable as opportunities occur to utilize other energy technologies that might arise in the future.

To the extent that propane burning vehicles could be drawn from different departments while being fueled and serviced by a single department, the project could, in a small way, contribute to interdepartmental cooperation within the University.

The University could increase its links with the local community through serving as a valuable source of local information on the performance of propane fueled vehicles. Further, the project could enable the University to assume a local leadership role with respect to the conservation of oil and air pollution control. Both are associated with the use of propane as a vehicle fuel.

4.5 Administrative Considerations

To maximize the potential benefits of conversion,

1. all vehicles with sufficient annual fuel consumption should be considered as potential conversion candidates, and

2. all propane vehicles should be fueled from the same bulk storage tank and serviced by the University's Central servicing facilities.

To allow vehicles from all departments access to the University's central fuel and service facilities would require certain administrative changes that could be effected through a system of interdepartmental charges. As such a system is already in place, implementation should be relatively effortless once the principle is agreed to by the relevant departments.

At present, vehicles used for farm and non-farm purposes are fueled from different bulk storage tanks. Historically, this has been necessary because the lower taxed farm gasoline is marked with purple dye to permit periodic inspections of road vehicles in rural areas. With propane however, the pressurized storage of the fuel makes spot inspections impossible and the colouring of the fuel irrelevant. Given this situation, there would appear to be no practical reason why the same bulk storage tank could not be used for both farm and non-farm propane vehicles. To implement this proposal, it would likely be necessary to obtain the consent of the Manitoba Sales Tax Department. In approaching the Department, the University could propose the maintenance of records that would enable it to determine the amount of propane on which tax should be charged. This could be accomplished by identifying farm purpose vehicles. The

University's existing distribution system currently permits the determination of fuel consumption by vehicle and thus this aspect of the proposal would require little in the way of administrative changes. Based on the existing consumption patterns of the vehicles to be converted, the University could probably negotiate an appropriate billing arrangement with the supplier vis-a-vis farm and non-farm propane prices once an agreement had been reached with the Sales Tax Department.

In the event that an agreement could not be reached with the Sales Tax Department, economic viability would have to be evaluated separately for farm and non-farm vehicles.

4.6 Management Attitudes

4.6.1 *Innovation*

In Section 3.8.1 it was noted that the way in which a technology is introduced can determine its 'success' or 'failure' within an organization. Based on observations over a seven-year period, it is the author's opinion that, on balance, changes at the University of Manitoba have been imposed in an autocratic manner. Historically, little time or effort have been spent consulting with or even briefing employees at lower levels with respect to proposed changes. This situation could be changed, but it should be noted that approaches to management are, to a certain extent, a matter of personal styles. A climate more favourable to the introduction of change in a manner conducive to its wholehearted acceptance and support might have to await a new generation of management.

Certainly, any changes in approach effected specifically for the propane project would likely be of a highly superficial nature. This being the case, lack of user support for the project and its subsequent failure to produce the expected benefits remain, in the author's opinion, strong possibilities.

4.6.2 *The Propane Conversion Project*

An extremely conservative and less complete version of this study based on November, 1981, cost information was presented to relevant management personnel early in 1982. This presentation showed that the conversion of only one vehicle--the garbage truck--could be a break-even proposition. The clear implication was that if a number of the University's 98 vehicles could be converted to propane, the University could reduce its operating costs.

The reaction to the presentation by the individual who would be largely responsible for implementing the project was extremely negative.

Specific objections to the project seemed to relate to the cost of training mechanics and the unavailability of commercial fuel facilities on a basis sufficient for the use of University vehicles. In fact, however, training is provided by at least one firm that performs vehicle conversions in the Winnipeg area. The training period is not lengthy. The major cost would be the salaries paid to employees off work during training. In the author's view, this objection lacks substance.

It may, in fact, be that certain University vehicles are used in such isolated areas that the use of propane would be very inconvenient or impossible. Such vehicles should, of course, be eliminated as potential conversion candidates. However, as indicated in Section 3.4.2, propane fuel facilities for vehicles have proliferated rapidly in Manitoba in recent years. Further, review and personal observation by the author indicate that a similar situation exists in Saskatchewan, Alberta, Ontario and even certain nearby states in the United States. Given existing propane distribution and the fact that the number of propane fuel facilities appear to be increasing, it is stretching credibility to suggest that all 98 of the University's vehicles have use patterns unsuited to the availability of propane.

A general objection to the proposal was that the potential savings were too small to justify the effort required to set up the project or, for that matter, even do a complete evaluation of the entire University fleet. The attitude that only large scale projects with vast potential benefits per project are worthwhile is not uncommon. Whether or not such a view has a shred of validity is irrelevant. The fact is that this view is part of the management psyche that was asked to evaluate and would be responsible for implementing the propane conversion project.

It is the author's view that in these circumstances there is a strong possibility that even if the project was undertaken it would be administered in a manner that would fail to achieve any projected savings.

4.7 Summary

This chapter has presented a methodology for evaluating the economic viability of propane conversion. The methodology has been demonstrated through a case study involving the use of University of Manitoba data. The case study illustrated that economic viability could be easily achieved if 5 vehicles were converted to propane.

Following consideration of economic viability, certian potential non-economic benefits of a propane convertion project were identified. Specifically, it was suggested that the project could:

1. provide University personnel with experience in the implementation and administration of a different energy technology,

2. act as a catalyst in the promotion of inter-departmental co-operation, and

3. help strengthen the University's involvement with the local community.

A review of administrative considerations indicated that certain adjustments would be necessary to administer and service the propane vehicles as a single group. These adjustments would require the co-operation of those departments controlling vehicles and the extension of the University's inter-departmental billing system.

To fuel farm and non-farm vehicles from the same bulk fuel tank would probably require consent of the Manitoba Sales Tax Department and the maintenance of certain vehicle consumption records.

The analysis concluded with a review of management attitudes toward innovation in general and propane conversion in particular. In general, the University management has tended to introduce change in an autocratic manner. Such an approach is, in the author's view, a factor that would operate to hinder the successful implementation of any proposed change. With respect to the propane conversion project, the individual who would be responsible for the project's implementation and administration was not interested. Lack of interest appeared to be due largely to the small scale of the project. The views of this individual were considered to carry the strong possibility that the manner in which the project might be implemented could result in the failure of the project to achieve the expected savings.

A general conclusion regarding project viability will be presented in Chapter V.

CHAPTER V

CONCLUSIONS AND RECOMMENDATION

5.1 Summary of Study Approach

This study has been concerned with the possible viability of propane as an immediate fuel option for the University of Manitoba. The study began with a brief introduction outlining certain aspects of the recent history of oil that led to the 1973 energy crisis and the search for alternative fuels.

In Chapter II, relevant aspects of various potential vehicle fuels that have been promoted, studied or dreamed about since the curtailment of oil supplies in 1973 were reviewed. A more detailed examination of propane supply, price and technology was presented in Chapter III.

In Chapter IV a methodology for evaluating the economic viability of propane conversion was outlined and the underlying rationale was explained. The application of the methodology was demonstrated through the presentation of University of Manitoba data as a case study. Potential non-economic benefits to the University were identified. Finally, administrative considerations and management attitudes vis-a-vis a propane conversion project at the University of Manitoba were identified and discussed.

5.2 Summary of Findings

1. In September, 1982, of a number of alternative fuels reviewed, propane was found to be the most promising immediate fuel option available to the University of Manitoba.

2. In general terms, propane supply was considered adequate and this situation was expected to continue in the future for both the short and intermediate terms. In terms of commercial availability, the situation vis-a-vis propane was considered adequate and improving.

3. Prospects of a continuing relative price advantage for propane vis-a-vis gasoline were considered reasonable.

4. Propane vehicle conversion technology was found to be effective, serviceable, readily available in Winnipeg, and moderately priced.

5. Discussions with propane dealers and users produced the conclusion that the manner in which a technology is introduced to an organization is a critical factor in the success or failure of the technology within that organization. Lack of acceptance by those dealing directly with the technology, can produce the failure of the technology to achieve projected results.

6. The economics of propane conversion at the University of Manitoba were shown to have improved between November, 1981, and September, 1982.

7. Given assumptions regarding the maintenance of an existing propane/gasoline price differential and the continuation of the existing fuel consumption pattern of selected vehicles, it was demonstrated that economic viability could be achieved at the University of Manitoba if only five of at least 98 vehicles were converted to propane. The payback period for the project was found to be slightly under 38 months while the break-even discount rate for the project was calculated to be about 30 per cent per year.

8. With respect to potential non-economic benefits, it was concluded that the project could:

    a. provide University personnel with experience in the implementation and administration of a different energy technology.

    b. act as a catalyst in the promotion of inter-departmental cooperation,

    c. help strengthen the University's involvement with the local community, and

    d. enable the University to assume a local leadership role with respect to the conservation of oil and air pollution control.

9. The cooperation of the Manitoba Government's Sales Tax Department, would be necessary if the same bulk storage tank were to be used for both farm and non-farm vehicles.

10. It was found that administrative adjustments necessary to accommodate a propane conversion project would be of a minor nature. For example, an already existing inter-departmental billing system would have to be extended and consumption on a per vehicle basis would probably have to be aggregated and summarized on a systematic basis.

11. The cooperation of a number of Departments might be required to permit all potential propane candidate vehicles to be integrated into a single conversion project in which fuel and servicing would be provided by a single department.

12. The University has tended to introduce change in an autocratic manner. This has meant that little has been done to gain, prior to their implementation, the acceptance of proposed changes by those who would be directly affected. In general, such an approach operates to hinder the successful implementation of any proposed change.

13. The individual who would be responsible for the implementation of the propane conversion project was found to have a negative attitude toward the proposal.

5.3 Conclusions and Recommendation

Based on the study performed and the findings outlined in Section 5.2, it is the author's opinion that, at a theoretical level, the conversion of a number of University of Manitoba vehicles would have been economically and administratively viable in September, 1982.

Based on a review of the experience of current propane users and dealers, it is the author's view that management attitudes toward change and the manner in which it is implemented can have a decisive effect on the success or failure of this type of project regardless of its theoretical economic and administrative viability. In terms of the University's operations, the propane conversion project would be a small scale undertaking. Management acceptance of the usefulness of small scale projects, as expressed by its willingness to administer them in a manner conducive to the realization of potential benefits, is vital to the successful implementation of the project. In general, change should be implemented in a manner that is non-threatening to those who would be directly affected by it and who, in turn, can affect the usefulness of an innovation to the organization. If these conditions can be met, the University should give consideration to a detailed evaluation of its entire vehicle fleet with a view to converting a portion of the fleet to propane.

APPENDIX A

CONVERSION FACTORS

1 US gallon	= .83267	Imperial gallons
1 Imperial gallon	= 4.546	liters
1 barrel	= 34.97	Imperial gallons
	= 159.0	liters
1 m^3	= 1000	liters
1 Btu	= 1055	joules
1 gallon of propane	= 110,000	Btu
1 liter	= 24,197	Btu
	= 25,527,835	joules
1 m^3	= 25,527,835,000	joules
	= .00002552784	PJ
1 PJ	= 39,173	m^3
1 ft	= .3048	m
1 gallon of gasoline	= 149,000	Btu

APPENDIX B

THE DERIVATION OF REGIONAL DEMAND

1. Sources: Canada. An Investigation of Propane

Canada. NEB. Canadian Energy

2. *Regional demand for propane* alone was not available in either of the source documents. However, provincial demand for LPG (propane and butane) was presented in the NEB document.[1] In deriving regional demand for propane the simplifying assumption was made that the LPG demand pattern could be applied to propane alone. This assumption places the regional demand estimates in the category of rough approximations. Because the Prairie Region so totally dominates Canadian propane production throughout the period for which estimates are developed, even a fairly large error in estimating demand could not affect conclusions regarding security of supply within the Region.

3. *The regional demand forecasts* for the Prairies were derived from the total demand projections presented in the NEB document.[2]

4. *In deriving regional demand* the following procedures were used:

   a. An amount set at 7.5 per cent of total domestic demand was deducted from total demand.[3] (This amount relates to propane use for miscible flooding --

---

[1]Canada. NEB. Canadian Energy. pp. 300-302.

[2]Ibid., p. 220.

[3]Canada. An Investigation of Propane. p. 81.

4. a. cont'd......

"an enhanced recovery process in which fluid capable of dissolving in the oil it contacts, is injected into a reservoir to form a single liquid that can move through the reservoir to a producing well more easily than the original crude oil."[4]

b. The Prairie Demand percentages, determined as outlined in point 2, were then applied to the net total Canadian demand after deducting the amount for miscible flooding.

c. The amounts determined in points 4 a. and 4 b. were added together to produce total Prairie demand.

5. *Data Limitations* forced the application of the 1980 regional demand percentage to 1981 total domestic demand. ((Total domestic demand as recorded (1980) and estimated (1981) varied by less than two per cent for the two years)).[5]

6. *The same procedures* were utilized in determining Manitoba demand.

7. *Example: - 1981 Prairie Demand*

Total Demand:	87.3 PJ or 3,420 x $10^3 m^3$
Miscible Flood:	3420 x .075 = 256.5
Prairie percentage: =	31.65
Net Prairie Demand: =	.3165 (3420.0 - 256.5)
	= 1001 x 10^3 m^3
Total Prairie Demand:	1001 + 256.5
	= 1257.5 x 10^3 m^3
Manitoba Demand:	= .0258 (3420.0 - 256.5)
	= 81.6 x 10^3 m^3

---

[4] Canada. NEB. Canadian Energy, p. xxxvi

[5] Canada. An Investigation of Propane, p. 22.

Sources Consulted

Articles and Brochures:

"Both Front and Rear, LPG Systems Can Take It" Butane-Propane-News. December, 1980.

Dyson, Freeman J. "Energy in the Universe" Energy and Power, (A Scientific American Book). San Francisco: W.H. Freeman and Company, 1971.

The engine fuel of tomorrow is here today. Brochure, n.p.: n.p., n.d., n. pag.

Hubbert, M. King. "The Energy Resources of the Earth" Energy and Power (A Scientific America Book) San Francisco: W.H. Freeman and Company, 1971.

IMPCO Carburetion, Ind. Everything you wanted to know about LP-Gas (propane) carburetion but didn't know who to ask. California: Impco Carburetion, Inc., 1980.

IMPCO Carburetion, Inc. Trouble-shooting Check List for Impco Equipped Propane Engines. California: Impco Carburetion, Inc., 1980.

Lilley, Wayne. "Why more fleets are turning to propane" Financial Times, December 7, 1981, pp. E5 and E9.

"Propane Proved Safe as a Motor Fuel" Butane-Propane News, July, 1980.

Books:

Bregha, Francois. Bob Blair's Pipeline: The Business and Politics of Northern Energy Development Projects. Toronto: James Lorimer & Company, Publishers, 1979.

Brooks, David B. Zero Energy Growth for Canada. Toronto: McClelland and Stewart Limited, 1981.

Brown, Lester R., Christopher Flavin and Colin Norman. Running on Empty: The Future of the Automobile in an Oil Short World. New York: W.W. Norton & Company, 1979.

Canada. Energy, Mines and Resources. Energy Statistics Handbook. Ottawa. Energy, Mines and Resources, March, 1982. (Updated at least annually).

Canada. Department of Energy, Mines and Resources. Low Temperature Starting Characteristics of Propane Fueled Automobile Engines. Project No. W-81-004-FI. Prepared by R.P. Shand, Research Council, February, 1982.

Canada. Department of Energy, Mines and Resources. The National Energy Program. Ottawa: 1980.

Canada. Department of Energy, Mines and Resources. The National Energy Program - Update, 1982. 1982.

Canada. Department of Energy, Mines and Resources. Propane Vehicles: Economical and Safe. n.p.: n.p., n.d.

Canada. Department of Energy, Mines and Resources. The Vapour Pressure/Temperature Relationship of Ethane in Propane Fuel. Project No. W-81-004-FI. Prepared by D.E. Mathers, P.Eng., and D. Waldron, Computer Programmer. Manitoba: Industrial Research Centre/Manitoba Research Council, April, 1982.

Canada. Federal Propane Vehicle Program Newsletter, n.p., n.d.

Canada. National Energy Board. Canadian Energy: Supply and Demand, 1980 - 2000. Ottawa: Supply and Services Canada, 1981.

Canada. Special Committee on Alternative Energy and Oil Substitution. Energy Alternatives. Ottawa: Supply and Services Canada, 1981.

Canada. Transport Canada. An Investigation of Propane as a Motor Vehicle Fuel in Canada. Prepared by R. F. Webb Corporation Ltd., in Association with Canadian Resourcecon Ltd., Cogesult Ltee., and Martec Ltd., Ottawa: February, 1982.

Canada. Transport Canada. Potential Propane Vehicle Fuel Market: Ontario, Manitoba, Saskatchewan, Alberta and British Columbia, 1980 - 1990. Prepared by Canadian Resourecon Limited. Vancouver: February, 1981.

Canada. Energy, Mines and Resources. Energy Statistics Handbook. Ottawa. Energy, Mines and Resources, March, 1982. (Updated at least annually).

Canada. Department of Energy, Mines and Resources. Low Temperature Starting Characteristics of Propane Fueled Automobile Engines. Project No. W-81-004-FI. Prepared by R.P. Shand, Research Council, February, 1982.

Canada. Department of Energy, Mines and Resources. The National Energy Program. Ottawa: 1980.

Canada. Department of Energy, Mines and Resources. The National Energy Program - Update, 1982. 1982.

Canada. Department of Energy, Mines and Resources. Propane Vehicles: Economical and Safe. n.p.: n.p., n.d.

Canada. Department of Energy, Mines and Resources. The Vapour Pressure/Temperature Relationship of Ethane in Propane Fuel. Project No. W-81-004-FI. Prepared by D.E. Mathers, P.Eng., and D. Waldron, Computer Programmer. Manitoba: Industrial Research Centre/Manitoba Research Council, April, 1982.

Canada. Federal Propane Vehicle Program Newsletter, n.p., n.d.

Canada. National Energy Board. Canadian Energy: Supply and Demand, 1980 - 2000. Ottawa: Supply and Services Canada, 1981.

Canada. Special Committee on Alternative Energy and Oil Substitution. Energy Alternatives. Ottawa: Supply and Services Canada, 1981.

Canada. Transport Canada. An Investigation of Propane as a Motor Vehicle Fuel in Canada. Prepared by R. F. Webb Corporation Ltd., in Association with Canadian Resourcecon Ltd., Cogesult Ltee., and Martec Ltd., Ottawa: February, 1982.

Canada. Transport Canada. Potential Propane Vehicle Fuel Market: Ontario, Manitoba, Saskatchewan, Alberta and British Columbia, 1980 - 1990. Prepared by Canadian Resourecon Limited. Vancouver: February, 1981.

Ontario. Ministry of Transportation and Communications and Ministry of Energy. Drive Propane: Preliminary Summary of Fleet Demonstration Results. March, 1982.

Ontario. Ministry of Transportation and Communication and Ministry of Energy. Switching to Propane: A Guide for Fleet Operators. Toronto: Ontario Government, August, 1981.

Ontario. Ministry of Transportation and Communications. Testing and Evaluation of Automotive Propane Conversion Equipment. Prepared by L. Segal, Department of Mechanical Engineering. University of Toronto. Toronto: Ontario Government. February, 1982.

Letter:

Bryant, W.J. Employee of the Government of Canada, Department of Energy, Mines and Resources. Letter. November 10, 1981.

Proceedings:

Economic Potential for Alternative Transportation Fuels: Methanol, Ethanol, Propane, Liquified Coal, Compressed Natural Gas and Hydrogen. Proceedings of a Seminar sponsored by the Canadian Energy Research Institute in November, 1981 in Calgary, Alberta. Calgary: Canadian Energy Research Institute, 1982.

Report:

Price Waterhouse, Chartered Accountants. The National Energy Program. 2nd ed., n.p.: Price Waterhouse, Chartered Accountants, November, 1981.

Statutes:

Manitoba. Manitoba Statutes, Chapter G40: An Act to Provide for the Imposition of a Tax on Purchasers and Users of Gasoline. Manitoba. December, 1980.

Manitoba. Manitoba Statues, Chapter M220: An Act to Provide for the Imposition of a Tax on Purchasers and Users of Motive Fuel. Manitoba: December, 1981.

Study:

Adelman, Henry G. "Methanol and Ethanol as Fuels for Spark Ignition and Diesel Engines." University of Santa Clara. California. June 20. 1980. n. pag.

Microfilm:

American Society for Testing and Materials. American National Standard. pp. 133-5

Interviews:

Blomquist, R.J. Manitoba Telephone System. Winnipeg, Manitoba. Interviews. August, 1982.

Exall, D. Petro Canada. Calgary, Alberta. Interview. February, 1982.

MacKinnon, Jan. CNG Fuel Systems Ltd. Vancouver, B.C. Interviews. September 24 and 25, 1982.

Mathers, D.E. Manitoba Research Council. Winnipeg, Manitoba. Interview. September, 1982.

Representatives, CIGAS Products Ltd. Winnipeg. Manitoba. Interviews. November, 1981, and September, 1982.

Representative. Government of Canada, Climate Services. Winnipeg, Manitoba. September, 1982.

Representatives. Metro Propane Ltd. Winnipeg, Manitoba. Interviews. November, 1981, and September, 1982.