2001-03-26

Building a Canadian Transportation Strategy for 2015 and Beyond

University of Guelph. Faculty of Environmental Sciences. Sustainable Transportation Advisory Group

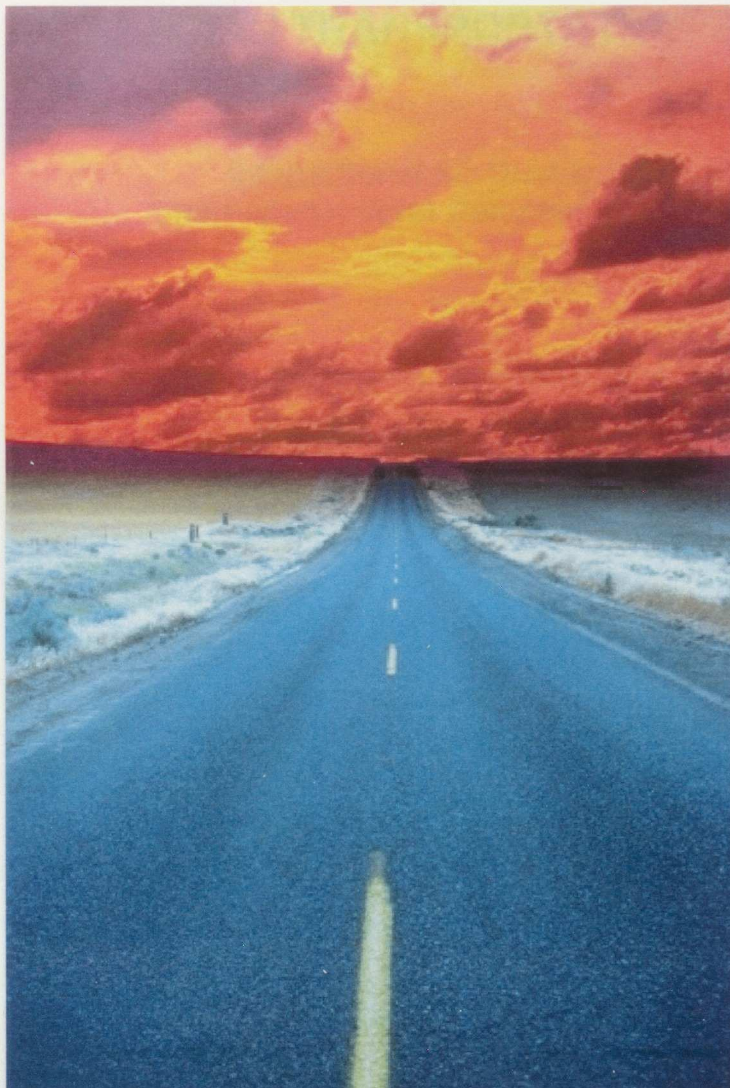
Mike Gunsinger

Marney Isaac

Ione Smith

BUILDING A CANADIAN TRANSPORTAION STRATEGY FOR 2015 AND BEYOND

International Air Quality Advisory Board of the International Joint Commission for the Great Lakes



SUSTAINABLE TRANSPORTATION ADVISORY GROUP

Mike Gunsinger, Marney Isaac, Ione Smith, Angela Vandersluis, Lindsay Snow, Karen Sutherland, Jill Lamberts, Robert Vitale

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FOR 2015 AND BEYOND

International Air Quality Advisory Board of the International Joint Commission for the Great Lakes

University of Guelph
Colloquium / Project in Environmental Sciences
March 26, 2001

Prepared by:

Sustainable Transportation Advisory Group (STAG)

Mike Gunsinger
Marney Isaac
Ione Smith
Angela Vandersluis
Lindsay Snow
Karen Sutherland
Jill Lamberts
Robert Vitale

Sustainable Transportation Advisory Group (STAG)
Faculty of Environmental Sciences, University of Guelph
Guelph, Ontario
N1G 2W1

March 26, 2001

Mr. John F. McDonald
International Air Quality Advisory Board, Secretary
International Joint Commission
Great Lakes Regional Office
100 Ouellette Ave. 8th Fl.
Windsor, ON
N9A 6T3

Dear Mr. McDonald:

We are pleased to submit this Canadian transportation strategy for 2015 and beyond, as assigned as part of the requirements for the course ENVS*4012 Colloquium/Project in the Environmental Sciences.

Over the past three months, we have conducted extensive research on passenger transportation in Canada necessary to prepare a strategy for 2015 and beyond. We have assessed practical options to reduce harmful emissions from passenger vehicles in Canada.

A web site has been developed to provide easy access to our report and other pertinent information, and a poster has been created displaying our project results. Please visit our website at http://www.members.home.net/robert-vitale/colloq/colloq.html, where you can view an electronic copy of our poster and other useful information.

We look forward to discussing this with you at your convenience.

Sincerely,

Mike Gunsinger	*Marney Isaac*	*Ione Smith*
Angela Vandersluis	*Lindsay Snow*	*Karen Sutherland*
Jill Lamberts	*Robert Vitale*	

MEMBERS OF THE SUSTAINABLE TRANSPORTATION ADVISORY GROUP

Team Members	Major	Area of Emphasis
Robert Vitale	Environmetrics	Environmental Economics / Policy
Angela Vandersluis	Environmental Protection	Environmental Stewardship
Karen Sutherland	Environmental Geography	Atmospheric Resources
Lindsay Snow	Ecology	Environmental Stewardship
Ione Smith	Natural Resources Management	Biotic Systems
Jill Lamberts	Earth and Atmospheric Science	Mathematical Modeling / Risk Assessment
Marney Isaac	Natural Resources Management	Plant Biology
Mike Gunsinger	Monitoring and Analysis	Water Resources

EXECUTIVE SUMMARY

The following report was prepared for the International Joint Commission on behalf of the Sustainable Transportation Advisory Group (STAG). It presents a Canada-wide transportation strategy for 2015 and beyond. The strategy focuses on passenger vehicles and includes an assessment of potential options based on an overriding goal of reducing the amount of harmful emissions currently being released into the atmosphere.

The report includes an outline of the current situation in Canada, including the current vehicle-engine mix, the amount and types of emissions being released, and policies pertaining to transportation that are presently in place. This analysis of the current situation in Canada is presented along with projections of future trends in vehicle ownership, emissions, and policies and combined with information gathered from rigorous investigation into alternative technologies. The technological options investigated were: alternative fuels, advanced internal combustion engines, hybrid vehicles, and hydrogen fuel cells. In order to evaluate which options would best reduce vehicle emissions, a comprehensive multi criteria evaluation was conducted.

The results of the multi criteria evaluations (MCEs) indicated that the implementation of gasoline-electric hybrid technology is the most promising option in the short-term (before 2015) to help meet the goal of emissions reduction. However, when long term (2015 and beyond) is considered, hydrogen fuel cell technology arises as a promising option. However, if hydrogen fuel cells are going to be the most commonly found vehicle in Canadian driveways, the associated costly infrastructure should become a priority today.

It was determined that a comprehensive transportation strategy must include direct consideration of increasing automobile dependency coupled with a growing population base. This was addressed in our report by a thorough investigation into initiatives aimed at reducing the social status associated with motor vehicles. A transportation strategy, which will be successful at reducing vehicle emissions, will include a combination of several of the initiatives outlined in this report. The viability of any future strategy will depend largely on public acceptance. For this reason, public attitudes and opinions were gauged by the use of a survey.

Using the above information, a specific strategy was developed, accompanied by a model framework, which can be applied to various situations at differing degrees of scale.

ACKNOWLEDGEMENTS

We thank the following individuals for making significant contributions to this project:

- *Don Irvine and M. Puddister, for assisting with our poster printing*
- *Tom Johnson for offering technical advice for our poster*
- *All those who assisted us by completing our survey*
- *Environment Canada for assisting us with our research by providing data*
- *John MacDonald of the International Air Quality Advisory Board of the International Joint Commission for the Great Lakes for providing us guidance throughout the extent of this project*

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1. INTRODUCTION

The increasing environmental impacts from the transportation sector are of growing concern and the repercussions are being felt around the globe. Rising vehicle emissions are postulated to contribute to the global climate change issue (Environment Canada, 1997c). The growing rate of fossil fuel consumption contributes to the unsustainable use of non-renewable resources. Passenger vehicles are the leading emissions contributor and account for 80% of the energy consumption from the transportation sector (OECD, 1997). Current attempts to reduce emissions are being offset by the number of vehicles on the road. There has been a ten-fold increase in the number of vehicles in Canada in the last 10 years, and there are now more than 700 million motor vehicles worldwide (OECD, 1997).

These increasing trends are now recognized as a global concern. International conferences initiated by the United Nations have addressed the issue of global climate change and have implicated the transportation sector. Many countries have recognized their contribution and have agreed to take action to reduce their emissions. Canada must also play an active role: governments, industry and society must take action toward reducing emissions and fossil fuel consumption. Evaluations of technological advances, policy, and education initiatives continue and their results must be implemented.

We, the Sustainable Transport Advisory Group (STAG), have developed a transportation strategy by assessing Canada's current situation, projecting future conditions, and conducting several multi-criteria evaluations (MCEs) of technological advancements. Through preliminary research, alternative fuels, advanced ICEs, gasoline-electric hybrids, and hydrogen fuel cells proved to be the most viable alternatives and are thus the focus of our report. Furthermore, a survey was constructed to assess public opinion along with an analysis of relevant policies and other initiatives. Both innovative policies and initiatives to reduce automobile dependency are integral aspects of the proposed transportation strategy. The final comprehensive strategy will take a holistic approach to promote sustainable transportation in Canada.

2. BACKGROUND

2.1 The Issues

Over recent decades there has been increasing concern over the adverse environmental effects posed by the transportation industry, and more specifically the use of passenger cars. Two major issues of concern are the release of air pollutants caused by the combustion of fossil fuels associated with motor vehicles, and the high rates of energy consumption that are leading to the rapid depletion of fossil fuel resources.

In recent years governments have introduced policies with the intention of reducing noxious vehicle emissions, energy consumption, increasing fuel efficiency. Industry has made vast technological improvements favouring these changes. However, these efforts are being offset by the increase in the number of vehicles on the road and the number of kilometres they are being driven. The increasing dependence on personal vehicles (i.e. cars and light trucks) stems from lifestyle choices and increasing suburban community development (Bunting and Filion, 2000).

In 1993 the transportation sector accounted for approximately 30% of energy consumption in Canada and approximately 31% of carbon dioxide (CO_2) emissions (Environment Canada, 1998). Emissions from the automobile create a large portion of the air pollutants emitted in Canada. In 1990, 17% of nitrogen oxides, and 20% of volatile organic compounds were attributed to the use of automobiles. Since 1995, the automobile has been responsible for 85% of the total CO_2 emitted by Canada's transportation sector, approximately 99,208 tonnes (Environment Canada, 1995).

2.1.1 Major Air Pollutants Emitted by Motor Vehicles

There are several types of air pollutants derived from both natural and anthropogenic sources. Air pollutants are defined as "airborne substances (either solids, liquids, or gases) that occur in concentrations high enough to threaten the health of people and animals, to harm vegetation and structures, or to toxify a given environment" (Ahrens, 1994). Currently, high levels of pollutants derived from human activities are offsetting the chemical balance of the atmosphere. This imbalance leads to adverse environmental effects such as acid precipitation, climate change, and photochemical smog (Ahrens, 1994).

Air pollutants can be categorized as either primary or secondary. Primary pollutants are those that enter the atmosphere directly, such as carbon monoxide emitted from automobiles, while secondary pollutants are a result of chemical reactions occurring between a primary pollutant and some other component of the atmosphere, such as the production of ground layer ozone (Ahrens, 1994).

Figure 1 illustrates the formulation of secondary pollutants from the combination of NO_2 and the sun.

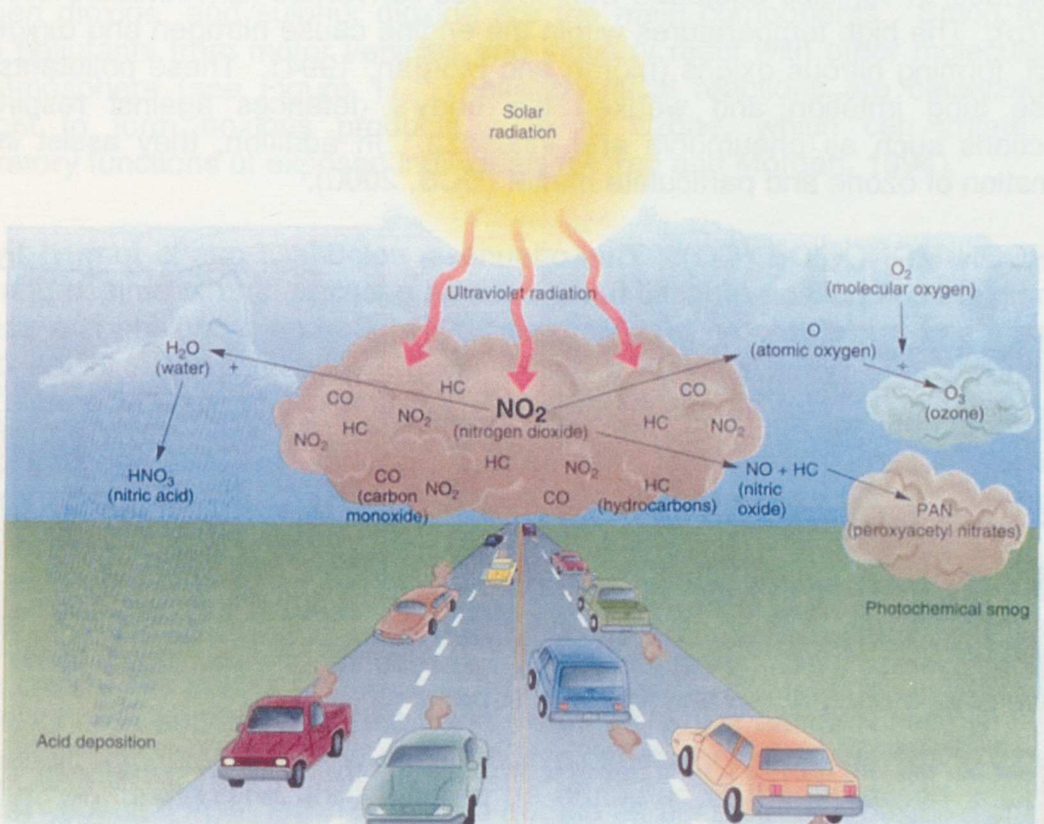


Figure 1: Photochemical reactions. (Christopherson, 1998, p. 67).

OZONE (0_3): Ozone is the main component of smog. Although very beneficial in the stratosphere where it blocks harmful UVB radiation, in the troposphere (the portion of the atmosphere nearest the earth's surface) ozone gas irritates the respiratory system, causing coughing, choking, and reduced lung capacity (Moran and Morgan, 1994). Ozone is a secondary pollutant created when hydrocarbons and nitrous oxides from automobile combustion react with sunlight (Moran and Morgan, 1994).

PARTICULATE MATTER (PM): These particles of soot, metals, and pollen give smog its murky colour. Fine particles (PM that is less than one-tenth the diameter of a human hair) pose the most serious threat to human health, penetrating deep into the lungs (UCS, 2000). In addition to direct emissions of fine particles from combustion processes, automobiles release nitrogen oxides, hydrocarbons, and sulphur dioxide, which generate additional fine particles as secondary pollutants (Environment Canada, 2000b).

NITROGEN OXIDES (NOx): The majority of these pollutants arise from agricultural practices. However, NO_2 is also formed during the combustion of fossil fuels in vehicles equipped with catalytic converters (Environment Canada, 1997b). The high temperatures within the engine cause nitrogen and oxygen to react, forming nitrous oxides (Moran and Morgan, 1994). These pollutants can cause lung irritation and weaken the body's defences against respiratory infections such as pneumonia and influenza. In addition, they assist in the formation of ozone and particulate matter (UCS, 2000).

CARBON MONOXIDE (CO): This odourless, colourless gas is formed by the incomplete combustion of fossil fuels, such as gasoline, and is emitted primarily by cars and trucks (Moran and Morgan, 1994). Carbon monoxide is a serious health hazard. When inhaled, it blocks the transport of oxygen to the brain, heart, and other vital organs of the body. Fetuses, infants, and people with chronic illnesses are especially susceptible to the effects of CO (UCS, 2000).

SULPHUR DIOXIDE (SO_2): Power plants and motor vehicles create this pollutant by burning sulphur-containing fuels, especially diesel fuel (Ahrens, 1994). Sulphur dioxide can react in the atmosphere to form fine particles and poses the largest health risk to young children and asthmatics (UCS, 2000). Sulphate aerosols form sulphuric acid in the presence of water, which is the main cause of acid rain (Moran and Morgan, 1994).

CARBON DIOXIDE (CO_2): During combustion, the carbon content of fossils fuels is oxidized and released as carbon dioxide (Environment Canada, 1997b). Although this gas does not exhibit toxic effects to humans, it has been identified as a greenhouse gas. The increasing concentration of CO_2 in the atmosphere is thought to be one of the main contributors to global warming (Moran and Morgan, 1994).

VOLATILE ORGANIC COMPOUNDS (VOCs): These compounds are commonly called hydrocarbons (HCs), chemicals that are made only of hydrogen and carbon atoms (Moran and Morgan, 1994). The production of VOCs is primarily associated with agriculture; however, incomplete combustion of gasoline by motor vehicles also contributes (Moran and Morgan, 1994). Due to the high volatility of gasoline, VOCs can also be emitted during the transfer of this fuel, as hydrocarbons can easily escape into the atmosphere (Moran and Morgan, 1994). A common example of a VOC is the greenhouse gas methane (CH_4), which, with increasing concentrations, is thought to be contributing to the enhanced greenhouse effect, but poses no known health risks (Ahrens, 1994).

In summary, the accumulation of these gases contributes to three major environmental problems: photochemical smog, acidic precipitation, and the enhanced greenhouse effect.

2.1.2. Photochemical Smog

Photochemical smog is defined as the "noxious mixture of air pollutants that can often been seen as a haze in the lower atmosphere" (Environment Canada, 2000b). Ground level ozone, particulate matter, carbon monoxide, nitrogen dioxide, and sulphur dioxide are the main components. Smog forms when pollutants from motor vehicles and industry react with other molecules in the atmosphere (see Figure 1). These chemical reactions are catalyzed by sunlight to form noxious products such as ozone, which can irritate the respiratory functions of exposed individuals (Moran and Morgan, 1994).

2.1.3 Acidic Precipitation

Acidic precipitation is caused by the emission of nitrogen oxides and sulphur dioxides into the atmosphere. There are both natural and human induced sources of these pollutants, however 95% are of human origin. Approximately 40% of nitrogen oxides are emitted by motor vehicles (Environment Canada, 2001). Although rain and snow are naturally slightly acidic with a pH of 5.6, highly acidic precipitation (with pH levels between 2.0 and 5.5) occurs in areas with air pollution that is high in nitrous and sulphuric oxides (Moran and Morgan, 1994). These gases interact with moisture in the atmosphere creating sulphuric and nitric acids, which dissolve in precipitation and increase the acidity (Moran and Morgan, 1994). Acidic precipitation alters the pH of soils and water on the earth's surface, which affects what can live in those environments. A variety of destructive effects including damage to forests, fish, human health, and buildings can be attributed to the increased acidity of precipitation (EPA, 2001b).

2.1.4 The Enhanced Greenhouse Effect and Global Warming

The greenhouse effect is responsible for the non-anthropogenic warming of the lower atmosphere and the hospitable average temperature experienced by life on earth, 12ºC. This is due to the fact that GHGs (water vapour, carbon dioxide, methane, and nitrous oxide) are able to absorb and re-emit infrared radiation (solar radiation reflected by the earth's surface), containing heat in the lower atmosphere that would otherwise be lost to space (Moran and Morgan, 1994). This natural effect is very important in maintaining life on the earth's surface. Unfortunately, a problem arises when concentrations of these gases in the atmosphere increase and cause an enhanced warming effect (EPA, 2001a). This is commonly referred to as the "enhanced greenhouse effect" and contributes to global warming. The emission of heat-trapping gases, carbon dioxide, VOCs, and nitrous oxides from motor vehicles, are adding to the natural concentrations found in the atmosphere and are of particular concern to many scientists (UCS, 2000). Although there are critics of the theory of human induced global warming, there is no dispute over the heat trapping capacity of these gases (EPA, 2001a), and the fact that average global temperatures are rising (Environment Canada, 1997b).

An international organization has been created to address the issue of global warming. The United Nations Environment Program and the World Meteorological Organization (EPA, 2001c) formed the Intergovernmental Panel on Climate Change (IPCC), in 1988. This Panel is comprised of experts and scientists from diverse fields. Their responsibilities include the "synthesis of peer-reviewed scientific literature on global warming studies, and the production of authoritative assessments of the current state of knowledge of climate change" (EPA, 2001c).

The IPCC published extensive reports in 1990 and 1996, and the next is due in 2001. These reports are the principal sources of material that are used in discussions and decision-making concerning the enhanced greenhouse effect. A monumental international conference concerning global climate change took place in Kyoto, Japan in 1997. This conference resulted in the Kyoto Protocol, an agreement that set the collective global target of reducing greenhouse gas emissions by about 5 % of 1990 levels by 2001 (Heanne and Petty, 1998). Of this, Canada voluntarily agreed to cut greenhouse emissions to 6% of 1990 levels by 2008. Following this conference the need for the reduction of GHGs was recognized. This has lead to increased research into technologies that emit less and initiatives that reduce the dependency of society on traditional technologies that have caused the increase in GHGs.

2.2 The Problem Statement

Burning fossil fuel produces hazardous emissions that appear to trigger adverse health problems for humans, enhance the greenhouse effect, and pollute the environment. Automotive transportation is a major contributor of fossil fuel emissions and, as our population grows, the number of automobiles on the road increases.

2.3 Definition of Sustainable Transportation

All levels of the government must adopt the goal of sustainable transportation in order to reduce vehicle emissions (NRTEE, 1996). Sustainable development, as conceived by the Brundtland Commission in 1983 is “development which meets the needs of the present without compromising the ability of future generations to meet their own needs” (Gordon, 1995). Environmentally sustainable transportation can be defined as transportation that does not endanger public health or ecosystems and uses renewable resources at below their rates of regeneration (OECD, 1996). Whenever “sustainable transportation” appears in this paper, the above definition is used.

Sustainable transportation involves three main components: changing people and the way that they act, changing prices, and changing technology (NRTEE, 1997). People's actions can be changed by reducing the need for transportation, eradicating the notion of the vehicle as a status symbol, and disseminating information about the negative environmental effects of automobile use. Prices can be changed by using market forces to enhance transportation efficiency, imposing stricter fuel taxes and clean car subsidies, and by using public policy to develop an economy that will work towards sustainability. Technology can be changed by using cleaner methods, such as improved engines, and by looking into the benefits of alternative fuels to reduce the impact of transportation on society and the environment (Gordon, 1995).

3. GOAL AND OBJECTIVES

The goal of this report is to provide a Canada-wide transportation strategy for 2015 and beyond. The strategy focuses on passenger vehicles and includes an assessment of potential alternatives that could reduce the amount of harmful emissions being released into the atmosphere.

Objectives

1. Research the current passenger vehicle-engine mix in Canada, the amount of emissions being released, and current policies. [Section 5.1]

2. Analyze the current situation and project trends in vehicle ownership, emissions, and policies. [Section 5.2]

3. Choose criteria for the evaluation of transportation alternatives. [Section 5.3]

4. Research potential transportation options including alternative fuels and fuel mixes, advanced ICEs, gasoline-electric hybrids, hydrogen fuel cells, and reduced automobile dependency. [Section 5.4]

5. Conduct multi-criteria evaluations (MCEs) on selected alternatives with respect to the criteria chosen in objective 3. [Section 5.5]

6. Develop Canada-wide strategy based on the outcome of objective 5. [Section 6.1]

7. Develop a poster displaying key issues and project findings, a web site to provide easy access to this study (http://www.members.home.net/robert-vitale/colloq/colloq.html), and a final report to be presented to the IJC in April 2001.

4. METHODOLOGY

The following methodology was employed In order to develop a strategy and meet the objectives as outlined by the client:

Phase 1: Literature Review
- Background information
- Current situation
- Data Collection
- Projections of Future Trends

Phase 2: Public Consultation
- Development and Execution of Public Survey

Phase 3: Development of Potential Alternatives

Phase 4: Data Analysis
- Multi-Criteria Evaluation

Phase 5: Report Writing and Poster Development

Phase 6: Website Creation

The multitude of stakeholders involved and the time required to implement new technologies make it difficult to forecast the future of transportation systems in Canada. To evaluate potential options for this strategy, alternatives were grouped into three categories:

1) Increased efficiency for ICEs
2) Alternatives to conventional ICEs
3) Reducing automobile dependency

The criteria chosen to evaluate the suitability of the alternatives were:

1) Emissions reductions
2) Ease of implementation
   a) Required infrastructure development
   b) Public acceptance
   c) Required policies
3) Long-term environmental sustainability

Options were assessed using MCEs to establish the most effective alternative for 2015 and beyond. The criteria were weighted in several ways in order to allow for the different priorities of the final decision-maker.

5. EVALUATION OF THE PROBLEM

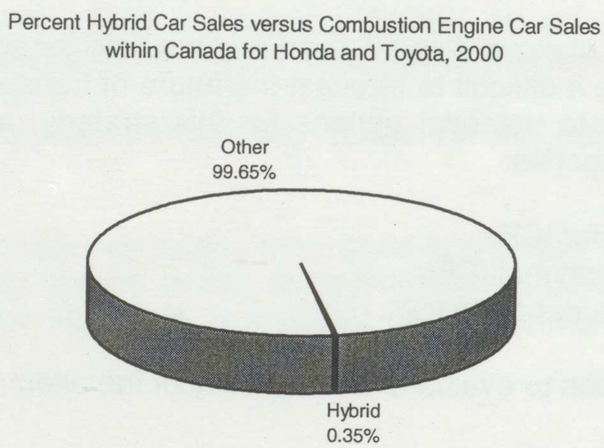
5.1 The Current Situation

5.1.1 Current Vehicle Composition

The current vehicle mix in Canada is comprised largely of unleaded gasoline-fuelled ICEs (ICEs). This is supplemented with only a very small percentage of alternative fuels and new technologies. These alternative fuels include natural gas, diesel, liquefied petroleum gas (propane), methanol and ethanol, supplemented by new technology in gasoline-electric hybrid and more efficient ICEs. Hydrogen fuel cells may also be a possibility in Canada in the near future. The following is a breakdown of new technologies and alternative fuels presently available in Canada.

5.1.1.1 *Hybrid Vehicles*

Presently, only Toyota and Honda have hybrid cars available on the market in Canada with total sales of approximately 600 vehicles (0.35% of total car sales) in 2000 (see Figure 2) (Japan Automobile Manufacturers Association



of Canada, 1998). Both Ford and Chrysler have produced hybrid vehicles, however, they have not yet been placed on the Canadian market (HybridCars, 2000).

Figure 2: Percentage of hybrid cars versus other cars sold by Honda and Toyota in 2000 (Japan Automobile Manufacturers Association of Canada, 1998 and Toyota and Honda Canada, 2001).

5.1.1.2 *Fuel Cells*

Many companies, including Ford, BMW, Chrysler, Honda and Toyota have undertaken research and technological advances in the field of zero percent emissions vehicles, specifically using hydrogen fuel cells (Ballard, 2001). Within Canada, efforts to upgrade and create a more efficient fuel cell are being enacted. Changes to this technology over the last few years have heightened the appeal of hydrogen fuel cells as a viable engine alternative. Car companies are strongly promoting this research. For example, Ballard, a Canadian power systems technology company, received 1.9 million dollars in January 2001 from Honda to continue research and development on the hydrogen fuel cell. Furthermore, a Ballard fuel cell transit bus fleet is being released in Vancouver to test this new technology (Ballard, 2001). However, at the moment, the infrastructure does not exist to accommodate the release of this new technology into the mainstream Canadian market. To make this possible, hydrogen-fuelling stations are needed, similar to that of gasoline fuelling infrastructure.

5.1.1.3 *Higher Efficiency Internal Combustion Engines and Alternative Fuels*

Higher efficiency ICEs are a potential alternative to the status quo. Currently, over 90% of vehicles on the road are conventional ICEs. Changes to these combustion engines, such as catalytic converters and spark ignition engines, are examples of recent improvements. Possible alternative fuels for combustion engines include natural gas, liquefied petroleum gas (propane), methanol, ethanol and gasoline-blended fuels. Availability and popularity of each of these fuels varies within Canada. Natural gas has minimal potential use as a transportation fuel due to the current limited infrastructure, whereas propane is available and used regularly (PNPPRC, 1999). Approximately 140,000 vehicles in Canada run on propane with 5000 public fuelling stations (ORTEE, 1995). Methanol, ethanol and gasoline-blended fuels are not conveniently available in Canada. Diesel accounts for 25% of fuel used in Canada in the year 2000. This percentage has remained almost constant during the last decade (NRTEE, 1996). The North-American vehicle market has shown less interest in diesel cars than the European market. This is due to the stigma attached to dirtier refueling stations frequented by large trucks and the false notion of lower quality and less efficient engines (Diem, 2000).

5.1.2 Current Emission Levels

5.1.2.1 *Greenhouse Gas Emissions*

Transportation is the single largest source of greenhouse gas (GHG) emissions in Canada, accounting for 25 % of the total in 1997 (Transport

Table 1: Passenger transportation activity, intercity and urban, 1997 (Transport Canada, 1999).

Mode		Activity		GHG emissions		GHG grams/pass-km
		Billion pass-km	**Percent**	**Kilotonnes**	**Percent**	
Intercity	Car/light truck	250.2	46.20%	27 523	33.40%	110
	Bus	14.2	2.60%	364	0.40%	26
	Train	1.4	0.30%	175	0.20%	123
	Aircraft	30.5	5.60%	4562	5.50%	150
	Ferry	0.9	0.20%	531	0.60%	570*
	Subtotal	**297.3**	**54.80%**	**33 155**	**40.20%**	**112**
Urban	Car/light truck	223	41.10%	47 882	58.00%	215
	Transit	12.7	2.40%	978	1.20%	77
	School bus	9.1	1.70%	510	0.60%	56
	Subtotal	**244.8**	**45.20%**	**49 370**	**59.80%**	**202**
Subtotal for car/light truck		**473.2**	**87.30%**	**75 405**	**91.40%**	
Total passenger		**542**	**100.00%**	**82 526**	**100.00%**	**152**

Passenger transportation, both intercity and urban, is dominated by the private light-duty vehicle (cars, vans, light trucks, and SUVs), which accounts for 87% of all passenger-kilometres traveled and 92% of the GHGs attributed to passenger transportation (Transport Canada, 1999).

From 1990 to 1995, GHG emissions from automobiles and light trucks running on gasoline increased by approximately 12.4% and GHG emissions from automobiles and light trucks running on diesel increased by approximately 11.0% (see Figure 4) (Transport Canada, 1999).

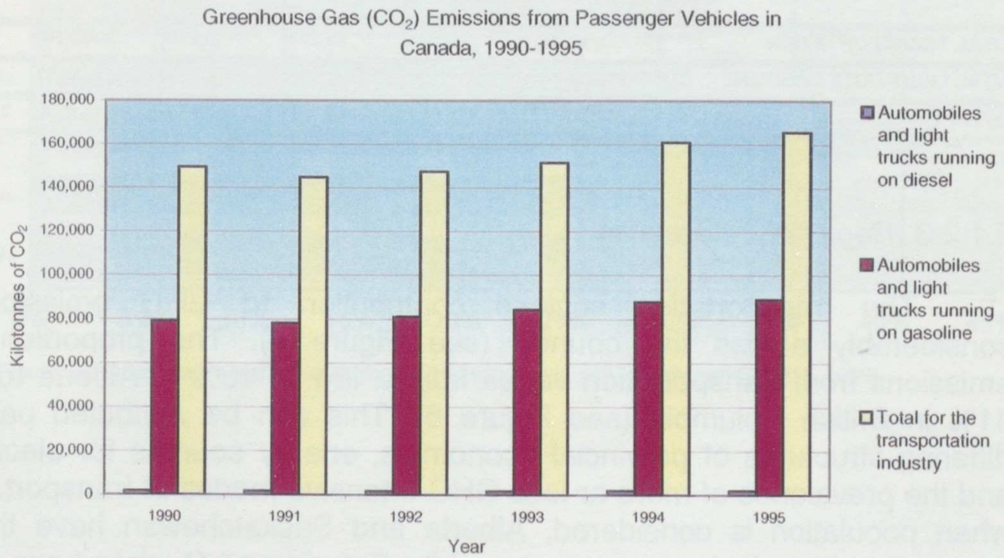


Figure 4: Greenhouse gas emissions from passenger vehicles in Canada, 1990-1995 (Environment Canada, 1997c).

5.1.2.2 *Criteria Air Contaminants*

There are seven air pollutants that are considered Criteria Air Contaminants (CAC) that are emitted predominantly into the atmosphere (Environment Canada, 2000c). The seven contaminants are Total Particulate Matter (PART), Particulate Matter 10 (PM 10), Particulate Matter 2.5 (PM 2.5), Carbon Monoxide (CO), Nitrogen Oxide (NOx), Sulphur Dioxide (SOx), and Volatile Organic Compounds (VOC) (see Table 2) (Environment Canada, 2000c).

In 1995, it was established that 57% of NOx emissions, 67% of CO, 5% of SO_2, 20% of PM and 28% of VOCs in Canada were attributable to transportation (Transport Canada, 2000).

Table 2: 1995 Criteria Air Contaminant emissions for Canada (tonnes) (Environment Canada, 2000c).

Category/sector	PART	PM10	PM2.5	SOx	NOx	VOC	CO
TRANSPORTATION							
Air Transportation	2,018	1,115	787	2,263	34,026	11,636	61,758
Heavy-duty diesel vehicles	32,075	32,075	29,498	32,807	378,300	48,540	224,438
Heavy-duty gasoline trucks	545	528	414	588	15,073	11,814	164,787
Light-duty diesel trucks	1,304	1,304	1,203	1,535	5,567	2,600	4,626
Light-duty diesel vehicles	379	379	347	632	1,978	747	1,667
Light-duty gasoline trucks	2,586	2,509	1,986	4,399	112,437	142,425	1,461,808
Light-duty gasoline vehicles*	4,870	4,717	3,256	11,048	273,396	355,873	3,558,667
Marine Transportation	8,438	8,129	7,379	58,000	118,578	37,449	103,310
Motor cycles	16	16	11	34	630	2,027	10,873
Off-road use of diesel	17,081	17,081	15,714	16,149	209,231	22,581	66,365
Off-road use of gasoline	4,414	3,867	3,393	1,005	25,395	93,111	1,027,393
Rail Transportation	19,492	19,492	17,933	7,226	115,604	5,608	22,022
Tire wear & Brake lining	4,362	4,313	1,353				
TOTAL TRANSPORTATION	**97,580**	**95,524**	**83,276**	**135,686**	**1,290,214**	**734,412**	**6,707,715**
TOTAL LIGHT DUTY GASOLINE	**7,456**	**7,226**	**5,242**	**15,447**	**385,833**	**498,298**	**5,020,475**
GRAND TOTAL	**15,684,465**	**5,370,694**	**1,519,149**	**2,653,571**	**2,463,971**	**3,575,202**	**17,127,836**

5.1.2.3 *Regional Differences*

The transportation sector's contribution to GHG emissions varies considerably across the country (see Figure 5). The proportion of GHG emissions from transportation varies from a low of 13% in Alberta to a high of 41% in British Columbia (see Figure 6). This can be attributed partly to the differing structures of provincial economies, energy sources for electric power, and the prevalence of more or less GHG-intensive modes of transport. However, when population is considered, Alberta and Saskatchewan have the highest transportation emissions per capita, while Ontario and Quebec have the lowest (see Figure 7) (Transport Canada, 1999).

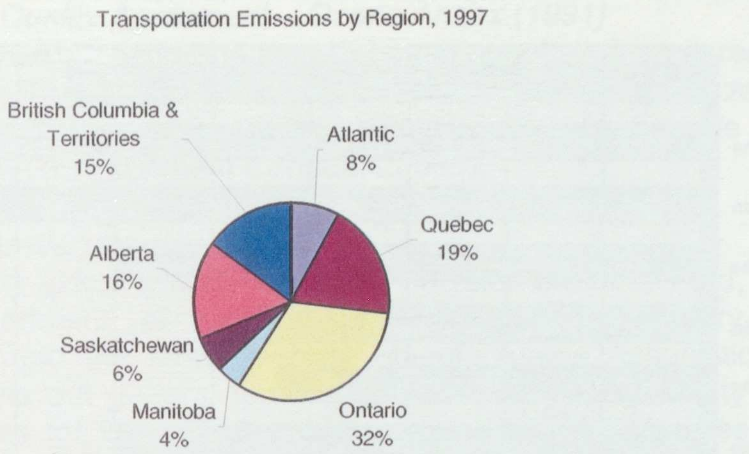


Figure 5: Provincial contributions to transportation GHG emissions (Transport Canada, 1999).

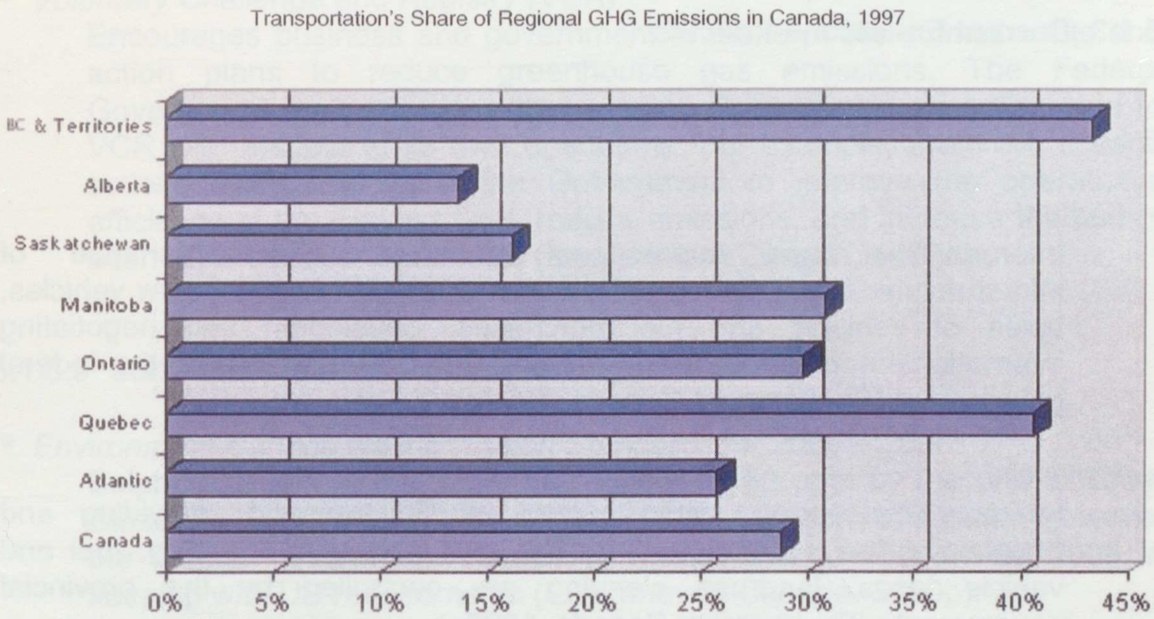


Figure 6: Transportation's share of regional GHG emissions, 1997 (Transport Canada, 1999).

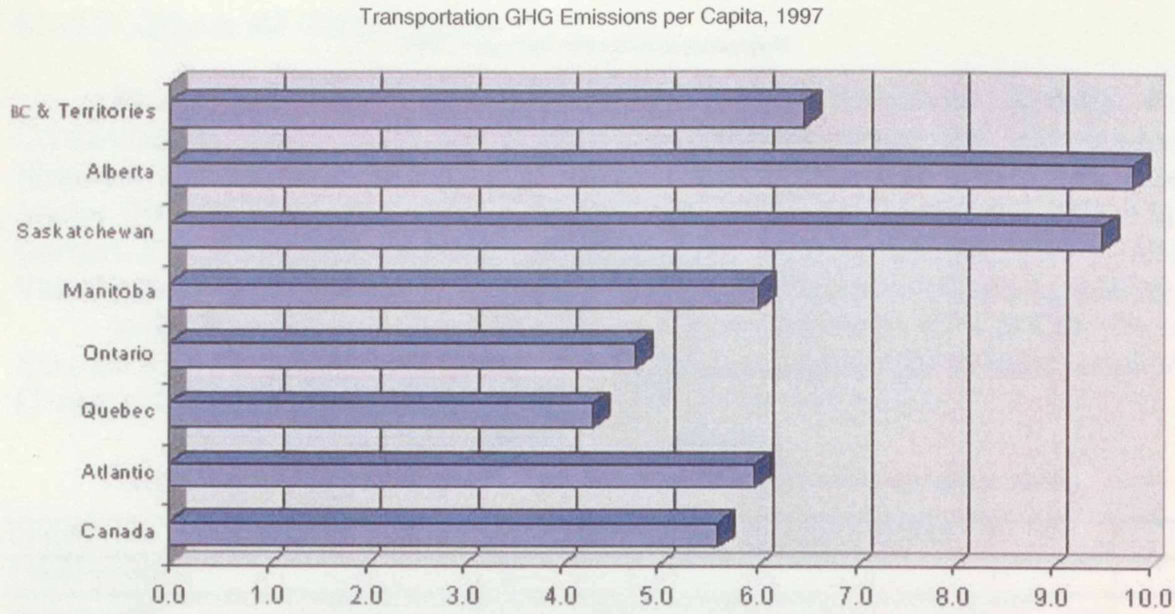


Figure 7: Transportation GHG emissions per capita, 1997 (Transport Canada, 1999).

5.1.3 Current Emissions Policies

5.1.3.1 *Jurisdiction*

- *Federal*

  Interprovincial and international transportation, maintenance of infrastructure, regulation of emissions and fuel efficiency of new vehicles, taxes of vehicles and fuel purchases, developing and negotiating international commitments and protocols are all controlled by the federal government (Environment Canada, 1997a).

- *Provincial*

  Interprovincial roads, traffic control, public transport, providing and maintaining the infrastructure for the above, vehicle licensing, fuel and vehicle taxes, land-use planning are controlled by the provincial governments (Environment Canada, 1997a).

5.1.3.2 *Agreements*

- *Kyoto Agreement (1997)*

  The main commitment on Canada's part was to reduce greenhouse gas emissions to 6% below 1990 levels by 2008. Refer to Section 2.1.4 for more elaboration (Heanne and Petty, 1998).

- *Canada – US Air Quality Agreement – Ozone Annex (1991)*
  In February 2000, Canada and the US began negotiating an agreement to reduce the transboundary flow of ground-level ozone. Ozone was identified as a major contributor to 5000 premature deaths due to smog and air pollution (Environment Canada, 2000b).

- *Memorandum of Understanding (MOU)*
  There currently exists a MOU between Chrysler Canada, Ford, General Motors, Department of the Environment, Ontario Ministry of the Environment, and the Motor Vehicle Manufacturer's Association. The agreement sets out general terms and conditions for light-duty car and truck emissions for 2001-2003 model years. This MOU serves to keep Canadian emission monitoring technology in line with US standards. This program is non-regulatory and calls for emissions control and monitoring to be kept in harmony with American models and to continue the practice of warranting all emission components on light-duty vehicles and trucks sold in Canada. A member may terminate the MOU by giving at least 90 days notice to the other parties (Environment Canada, 2000b).

- *Voluntary Challenge and Registry (VCR)*
  Encourages business and government to make public commitments and action plans to reduce greenhouse gas emissions. The Federal Government itself has submitted a letter of intent and an action plan to VCR with respect to its own operations. For example, there are several actions underway within the Government to improve the operational efficiency of the Federal fleet, reduce emissions, and increase the use of alternative transportation fuels (Environment Canada, 1997a).

5.1.3.3 *Current Standards/Regulations/Legislation*

- *Environment Canada New Emission Standards for 2004 – 2006*
  Sulphur content in fuel must be reduced to 30 ppm by the end of 2004. Diesel fuel can contain a maximum level of 500 ppm of sulphur, however the federal government intends to reduce this to 15 ppm by 2006 in keeping with US requirements (Environment Canada, 2000b).

- *Canadian Environmental Protection Act (CEPA)*
  This act will provide the federal government with the ability to enforce pollution abatement and emission regulations. Under CEPA (1999), particulate matter that is less than or equal to 10 microns is considered toxic and as a result specific emission reduction targets with timetables will be required to be submitted by key industrial sectors (Environment Canada, 2000b).

- *Canadian Transportation Act 1996*
  The Canada Transportation Act of 1996 declares that a safe, economic, efficient and adequate network of viable and effective transportation services should be accessible to all Canadians and that the best use of all available modes of transportation at the lowest total cost is essential to serve the transportation needs of shippers and travelers and to maintain the economic well-being and growth of Canada. These objectives will be achieved when all carriers are able to compete under conditions ensuring that safety standards are met, competition is viable, transportation is recognized as a key to regional development, and that fares and rates promote accessibility. With respect to the environment, it is expected that each transportation carrier will bear a fair proportion of the real costs of resources and facilities provided (Transport Canada, 1996).

- *Alternative Fuels Act*
  This act, taken into effect in 1997, serves to encourage the use of alternative fuels for federal government-owned vehicles (automobiles, light and medium duty trucks, vans and buses). The goal is for at least 75% of government driven cars to be alternative fuels cars by 2004 (Gov. of Canada, 2000a). In this act, an alternative fuel refers to ethanol, methanol, propane, natural gas, hydrogen or electricity. In the 1997-2000 fiscal years, the federal government surpassed its goals in alternative fuel vehicle purchases and has therefore complied with the act (Gov. of Canada, 2000b).

- *Meeting US Standards*
  The federal government of Canada has committed to meeting or exceeding US vehicle emissions standards by 2004. Specific implementation will be published in a formal statement in the near future (Environment Canada, 2000b). Canada's emission regulations for light-duty cars and trucks were aligned with the US Environmental Protection Agency's (EPA) in 1988 and were updated in 1998 under the Motor Vehicle Safety Act. In 1999 these regulations were transferred to the Canadian Environmental Protection Act. The US EPA and the American automotive industry are implementing an initiative called the Voluntary National Low Emission Vehicle (NLEV) program to introduce a generation of cleaner automobiles and trucks (Environment Canada, 2000b).

- *Clean Vehicles and Fuels Policy of B.C.*
  B.C. has committed to adopting the toughest standards in North America. In 1995 B.C. adopted the California Low Emission Vehicle standards before any standards were established across Canada (Government of B.C., 2000a).

- *Ontario Tax for Fuel Conservation*
  This tax was introduced to reward fuel conservation behaviour when purchasing new cars. This tax evolved from the Liberal Provincial government of 1989's Tax on Fuel-Inefficient Vehicles. Anything above the consumption rate of 9.5-litres/100 km was taxed. The New Democratic Party in 1991 doubled this tax rate and extended the coverage to over 250 car models. The current Conservative government of Ontario has since lowered the tax rates, especially those of sports cars, and has introduced a $100 rebate for the purchase of extremely fuel-efficient cars of less than 6.0 litres/100 km (IISD, 2001).

5.1.3.4 *Initiatives*

- *Partnership for a New Generation of Vehicles (PNGV)*
  The PNGV is a research and development partnership between Chrysler, Ford, General Motors, and the US federal government. It promotes improvement in technologies that will lead to better emissions, safety and fuel-efficiency by 2004. The overall goal is to triple the fuel efficiency of today's vehicles while maintaining size, performance, and cost (ORTEE, 1996).

- *Pollution Abatement Funding*
  Between 1991 and 1995 the federal government decreased its pollution abatement and control expenditures from $341 901 000 to $242 652 000. Within the provinces, however, Newfoundland has nearly doubled its figures, while the rest all decreased their spending in this area. Of particular note is Saskatchewan who decreased its spending by 80% and Nova Scotia who decreased spending by 50% (Statistics Canada, 1995).

- *Research and Development*
  The National Pollutants Release Inventory produces publicly accessible information on toxins released into the air, and has recently been expanded by 50% (Environment Canada, 2000b). The federal and provincial governments have doubled its air pollution monitoring with a focus on the National Air Pollution Surveillance Network (Environment Canada, 2000b). Energy-related funding by provincial and federal governments has greatly decreased since 1983, and renewable energy research receives only 20% of the funding that fossil fuel research receives (Natural Resources Canada, 1997).

- *Auto$mart*
  Natural Resources Canada developed the Auto$mart program in 1995 to provide Canadian vehicle consumers with tips on buying, driving, and maintaining vehicles in ways that will reduce fuel consumption. Auto$mart includes fuel consumption guides and an on-line Energuide that allows

fuel consumption comparison between models (Natural Resources Canada, 2000).

- *National Action Program on Climate Change*
  A National Action Program initiated by the Federal Government of Canada, which includes several broad based climate change mitigation measures such as, Voluntary Challenge and Registry (as discussed previously), a National Communication Program, Joint Implementation, and International Cooperation (Environment Canada, 1997a).

- *Task Force on Cleaner Vehicles and Fuels 1994*
  The Canadian Council of Ministers of the Environment established this task force in November 1994 to develop options and recommendations for a National approach to new vehicle emissions, efficiency standards, and fuel formulations. The Task Force reported with recommendations in October 1995. Recommendations included more rigorous regulation concerning emissions, heavier taxes on fuels and vehicles, restrictions on the use and ownership of private vehicles, and massive investment in public transport and alternative fuels.

- *Centre for Sustainable Transport*
  The Government of Canada has provided start up funds for the Centre which is to be located in Toronto. The Centre's core activity is to be the development and application of indicators of the performance of transport systems in relation to sustainability and the publication of an annual evaluation of transport systems in Canada.

- *Ontario Round Table on the Environment and Economy (ORTEE)*
  ORTEE was established in 1989 as a result of recommendations that came out of a report after the Bruntland Commission's visit to Canada in 1986. Membership of the ORTEE includes industrialists, academics, resource and economics ministers, First Nations representatives, and community leaders. The objectives of ORTEE are to develop a provincial strategy for sustainable development, support relevant research, and to develop an outreach and education program to spread awareness of sustainable development. The ORTEE has produced several reports dealing with policy initiatives and incentives to reducing vehicle emissions including feebates, congestion pricing, parking policies, new CAFÉ standards and a gasoline tax increase (ORTEE, 1995).

- *Ontario Drive Clean Program*
  A mandatory vehicle emissions-testing program designed to identify those vehicles that no longer operate in compliance with acceptable emission standards. Under the program designated vehicles in areas with serious smog problems must pass a clean air test. Vehicles that fail must be repaired and then retested. When fully implemented the program is

predicted to cut smog by up to 22% in the program area. Preliminary review of year one data for testing in the Greater Toronto Area and the Hamilton-Wentworth Area indicate estimated significant reductions of 11.8% HC emissions, 11.7% CO_2 emissions, and 4.7% NOx emissions (Government of Ontario, 1999).

- *B.C Air Care*
  AirCare in British Columbia, the Motor Vehicle Emissions Inspection and Maintenance (I/M) Program, has been law since 1992. The program was developed to address the deteriorating air quality of the Lower Fraser Valley. Over the first seven years of the program, approximately one in three vehicles (508,443) tested was identified as having excess emissions. As a result of proper repairs, total emissions from all vehicles has been reduced by more than 30%. On September 21, 2000, the province released an independent review of the AirCare program. The major findings of the review were that "AirCare continues to be one of the most effective I/M programs in North America" (Government of B.C., 2000b).

5.2 <u>Projections and Analysis</u>

5.2.1 Trends in Vehicle Ownership in Canada

The number of road vehicles in Canada has been growing at a steady rate. From 1990 to 2000, vehicle registration in Canada had increased from 15.1 million vehicles to 16.3 million vehicles. The National Round Table on the Environment and Economy (NRTEE) has predicted a continued increase in vehicles on the road in Canada as a response to population growth and economic activity (NRTEE, 1996). They also predict an annual average growth rate for road transportation in Canada between 1991 and 2020 to be 1.6% growth. Forecasting has been undertaken by researchers to predict car ownership and fuel consumption for 2015 based on 1995 data. It has been predicted that Canada will see an increase of 0.12% in car ownership by 2015 (Dargay and Gately, 1997).

5.2.2 Kyoto and Transportation

In December 1997, Canada, along with other developed countries, negotiated the Kyoto Protocol under the United Nations Framework Convention on Climate Change. If the Protocol were ratified, Canada would agree to reduce its emissions of GHGs by 6% below 1990 levels during the period from 2008 to 2012 (Transport Canada, 2000).

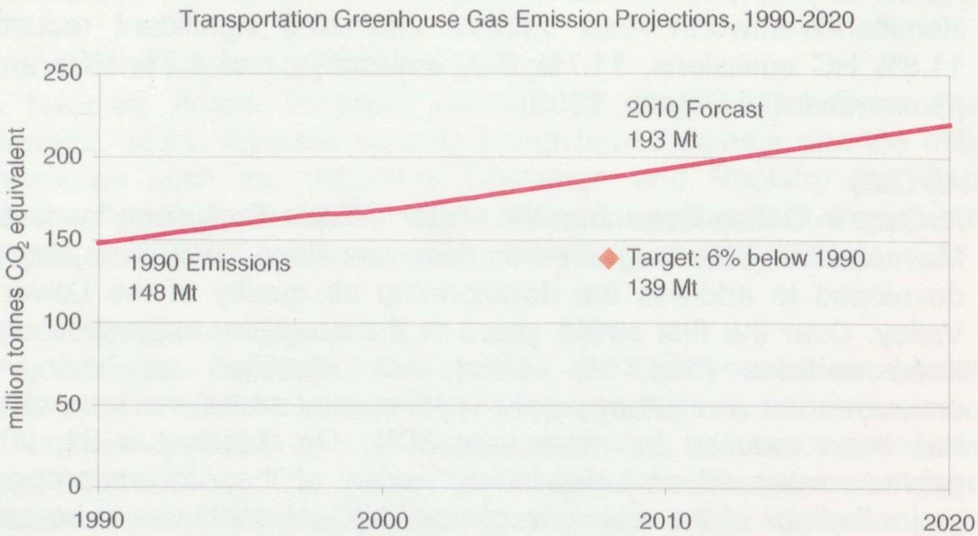


Figure 8: Kyoto protocol implications: transport sector greenhouse gas emission projections, 1990-2020 (Transport Canada, 1999).

The largest source of transportation emissions – on-road gasoline – is expected to increase by 44% between 1990 and 2020 (Transport Canada, 1999). If current trends continue, greenhouse gas emissions from transportation are expected to exceed 1990 levels by 32% by 2010 and 53% by 2020 (Figure 8). To achieve the targeted 6% reduction from 1990 levels, as stated in the Kyoto protocol, emissions from transportation would have to be reduced by about 54 megatonnes in 2010 (Transport Canada, 1999).

5.2.3 Emissions From Passenger Vehicles

The challenge of reducing emissions from personal transportation is illustrated in the table below. Canada is facing continued growth in the number of vehicles, and each vehicle is being driven farther (Table 3). Although energy efficiency in transportation is forecast to improve by 0.7% per year between 2000 and 2020, this is likely to be overwhelmed by the increased use and number of vehicles. Past improvements in vehicle fuel economy have also been eroded due to consumer preferences for vehicle performance and size, as well as regulated changes to improve air quality and safety, which add weight to the vehicle and reduce fuel efficiency (Transport Canada, 2000)

Table 3: Growth in number and use of light-duty vehicles (Transport Canada, 1999).

	1990	1995	2000	2010	2020
Automobiles (millions)	11.1	10.31	9.37	9.72	12
Average distance per vehicle (kms)	16 738	18 786	19 817	19 839	19 584
Light trucks (millions)	3.45	4.34	5.16	6.81	8.61
Average distance per vehicle (kms)	23 167	22 166	22 209	21 612	21 181
Total vehicle-kms travelled (billions)	**265.72**	**289.78**	**300.2**	**339.92**	**407.86**

5.2.4 Transportation Energy Demand

Overall, transportation energy demand (Table 4) is expected to grow by 0.66% per year between 1997 and 2020. However, there are marked regional differences, with Alberta exhibiting the highest growth rate at 0.95%, and Ontario next at 0.71%. With the exception of the Atlantic Provinces (0.68%), all other regions are growing at less than the national rate (Transport Canada, 2000)

Table 4: Transportation energy demand by region, 1997 (petajoules) (Transport Canada, 1999).

						Annual Change	
Region	**1990**	**1997**	**2000**	**2010**	**2020**	**1990 - 2020**	**1997-2020**
Atlantic	202	209	224	245	274	0.65%	0.68%
Quebec	424	450	454	500	573	0.55%	0.46%
Ontario	681	765	797	901	1058	0.94%	0.71%
Manitoba	89	93	97	106	117	0.57%	0.57%
Saskatchewan	108	132	132	144	161	0.98%	0.39%
Alberta	306	379	392	471	557	1.45%	0.95%
BC & Territories	290	374	379	426	481	1.29%	0.57%
Canada	**2100**	**2402**	**2476**	**2794**	**3222**	**0.96%**	**0.66%**

5.2.5 Policy

5.2.5.1 *Summary of Current Vehicle Policies in Canada:*

Agreements

Current agreements aimed at the reduction of vehicle emissions tend to take a voluntary approach. Parties involved in current agreements include federal and provincial governments, the automobile industry, and the international community. None of the existing agreements are legally binding.

Standards/Regulations

There exists a general trend to align Canadian emission standards with those in he US. This approach has not been adopted at a provincial level except for in the case of B.C. There are not many tax incentives in place in Canada aimed at reducing vehicle emissions.

Initiatives

The only initiatives showing quantifiable emission reduction results are mandatory vehicle inspection and maintenance programs set up by the governments of Ontario (DriveClean) and B.C. (AirCare). There are no shortage of recommendations for action coming from committees and commissions reporting on emission reduction. However, these recommendations rarely end up being implemented at a legislative level. The concept of sustainability is increasingly being applied to the development and reform of the transportation sector.

5.2.5.2 *Analysis of Current Policy and Its Implications on Future Emission Levels*

The current policies and initiatives set forth by Canadian federal and provincial governments have been sharply criticized for their inability to achieve short-term goals in vehicle emission reduction. At the recent conference on air quality at the Hague, Canada admitted to being behind the year 2000 commitment set forth at Kyoto (1997) for reducing carbon dioxide emissions (Sierra Club, 2000). The two main criticisms that appear in the literature are that specific quantitative emission reduction goals are seldom included in policies and initiatives and that there is too much reliance on voluntary action to reduce vehicle emissions (NRTEE, 1996 and Sierra Club, 2000).

The lack of specific targets for vehicle emission reduction initiatives tends to contribute to projects that do not have an impetus for producing tangible results (NRTEE, 1996). For instance, the National Action Program on Climate Change (NAPCC) provides a list of the activities of government departments that are being active in the reduction of GHGs but does not include quantitative goals for these activities (NRTEE, 1996). Similarly, the voluntary approach has been criticized for not resulting in enough progress towards emissions reductions.

Many ministers, including Ralph Goodale, Minister of Natural Resources, believe that a voluntary approach on the part of citizens and companies is the best way to achieve emission reduction goals (Sierra Club, 2000). However, many environmental and public interest groups disagree with this approach because it is thought that, without mandatory compliance, marketplace incentives are likely to conflict with emission reduction goals. As a result reduction goals will not be reached.

5.3 Assessment of Criteria

5.3.1 Emissions Reductions

The criterion of 'emissions reductions' was chosen as a means of evaluating the environmental impacts of a proposed alternative. By reviewing emissions reductions of current and new technologies, it was possible to compare the alternatives based on the goal of reducing emissions.

5.3.2 Ease of Implementation

The following three criteria were chosen to reflect the ease of implementation of a proposed alternative.

5.3.2.1 *Required Infrastructure Development*

This criterion will assess the degree of infrastructure development that is required to implement the proposed option.

5.3.2.2 Public Acceptance

Public acceptance encompasses cost to the consumer, public safety, and society's willingness to adopt the proposed transportation option.

5.3.2.3 *Required Policies*

This criterion assesses the extent of policy formation required to implement the proposed option. This impart reflects its political attractiveness.

5.3.3 Long-Term Sustainability

This criterion assesses the dependency of the alternative on non-renewable resources and the impact on the biophysical environment of each proposed option. This distinguished between short and long-term options and stressed the need for a viable solution for future generations.

5.4 Alternatives

5.4.1 Higher Efficiency Internal Combustion Engines and Alternative Fuels

5.4.1.1 *Alternative Fuels and Fuel Mixes*

The use of alternative fuels in ICEs provides some possibilities in the reduction of GHGs as well as other emissions. The three main alternative fuels reviewed here are methanol, ethanol and propane. This information is supplemented with a summary chart comparing alternative fuel emissions to gasoline emissions (see Table 5). Within this report, these fuels will be considered collectively as one alternative in the MCEs. This is due to the similarity of each fuel under the specific criteria. However, each individual fuel is evaluated separately below.

Methanol:

Methanol can be produced from natural gas in large petrochemical refineries, from coal or from biomass. Methanol is commonly sold as a mixture of gasoline containing 85% methanol and 15% gasoline, referred to as M85. A fuel comprised of 100% methanol is also available, which is referred to as M100 (Sperling, 1995).

Ethanol:

Ethanol is an alcohol fuel produced by fermentation of a farm crop, usually corn, by converting the cellulose into fuel (Sperling, 1995). Ethanol is also usually sold in a mixture containing 85% ethanol and 15% gasoline, referred to E85, or like methanol, it can be produced as a pure fuel, E100 (PNPPRC, 1999).

Propane (Liquefied Petroleum Gas):

Propane is a natural gas liquid produced during the oil refinery process. Propane can contain ethane, butane, and propylene, each of which affects the purity of the gas. It was the first alternative fuel accepted by the consumer as an alternative to gasoline (Gushee, 1992).

Emissions Reductions

Methanol:

M85 has only a small impact on reducing ozone pollution and is only slightly better at reducing emissions than unleaded gasoline. However, M100, if more widely used, would have substantial reductions in ozone pollution (Sperling, 1995). NO_X and hydrocarbons emissions from M85 are slightly lower than those of gasoline. Furthermore, smog-forming emissions are generally reduced by 30-50% when using methanol fuel as compared to gasoline. In M85, total toxic air pollutants are 50% less and in M100 toxic air pollutants are non-existent. However, for methanol and gasoline, the CO emissions are equal (PNPPRC, 1999).

Ethanol:

Ethanol is comparable to methanol when reviewing emissions reduction. When burned, ethanol produces 30-50% less smog forming emissions than gasoline. Air toxins are reduced by 50% (PNPPRC, 1999).

Propane:

Generally, propane has less CO emissions than gasoline vehicles, however, there may be higher NOx emissions. CO_2 emissions are approximately 13 to 15% lower than gasoline emissions. Furthermore, the emissions produced during production of propane are the lowest of all conventional and alternative transportation fuels. As a whole, CO_2 emissions from propane are 25% less than those of gasoline (ORTEE, 1995).

Infrastructure

Methanol and Ethanol:

Both methanol and ethanol are currently more expensive than gasoline, although ethanol is slightly cheaper than methanol. In addition, production and distribution infrastructure of methanol and ethanol will result in an increase in cost (PNPPRC, 1999). Methanol's success is dependent on the development of more environmentally friendly production. The auto industry is quite accepting to the use of methanol, as it requires very little additional costs. Fuel-flexible vehicles can be produced at the same cost as regular gasoline burning vehicles (Sperling, 1995). Ethanol's use is widespread but is very dependent on the availability of crops and crop wastes to be used for production (Sperling, 1995).

Propane:

The infrastructure for implementation of propane gas is already in place, and thus requires no additional cost. There are currently 140,000 propane fuelled vehicles and 5,000 public fuelling stations in Canada (ORTEE, 1995).

Public Acceptance

Methanol and Ethanol:

Although these fuel blends are easily implemented due to their easy replacement of gasoline, one main economic disadvantage is the overall fuel efficiency. Both ethanol and methanol have lower energy content. Ethanol lasts only approximately two-thirds the distance for the same volume of gasoline and methanol has only half the energy content of gasoline. However, since methanol and ethanol run cleaner in an engine, long-term maintenance costs may be reduced (PNPPRC, 1999).

Propane:

Due to the fact that the price of propane is comparable to the price of unleaded gasoline prices, the public will not see cost difference between the two fuels thus making this fuel easily accepted (PNPPRC, 1999). Furthermore, propane is a safe and widely available fuel that has been used in Canada since the 1920s (ORTEE, 1995).

Long-Term Sustainability

Methanol, Ethanol and Propane:

The sustainability of these alternative fuels in the short and long term is not very high. Although both alternative fuels offer easy implementation and a reduction in emissions, this reduction is not high enough for true sustainability of this alternative.

Table 5: Comparison of alternative fuels to gasoline (ORTEE, 1995).

Emissions	Gasoline	Ethanol – E85	Propane – LPG	Methanol – M85
Greenhouse Gases				
Water vapour	Yes	More	More	More
Carbon dioxide	Yes	Less	Less	Less
Methane	Yes	Equal	More	Equal
Nitrous oxide	Yes	Unknown	Unknown	Unknown
Carbon monoxide	Yes	Equal	Less	Equal
Nitrogen oxides	Yes	Equal	Equal	Equal
Nonmethane Organic Compounds				
Methanol	No	No	No	More
Ethanol	No	More	No	No
Formaldehyde	Yes	More	Equal	More

Acetaldehyde	Yes	Equal	Less	Equal
Ethane	Yes	Equal	Equal	Equal
Total Ozone Precursors	Yes	Less	Less	Less
Sulphur oxides	Yes	Less	No	Less
Particulate matter	Yes	Less	Less	No

5.4.1.2 Advanced Internal Combustion Engines

Modifications to traditional transportation vehicles are solutions to lowering environmental costs and increasing fuel efficiency (MacLean and Lave, 2000). Over 90% of current vehicles on the road are conventional ICEs. Therefore, reducing emissions by modifying ICEs may be the easiest in terms of socio-economic disturbance. The conventional ICE only converts about 13 – 18% of available energy provided from the crude oil into useful propulsion (Ford, 1999). Altering current vehicles can result in improved vehicle performance, speed, reduced environmental impact, and lower cost of ownership (Ford, 1999). Hence, modified vehicles are termed advanced ICEs.

There is clearly still potential for further improvement to ICEs. Nonetheless, any gasoline driven engine will still emit pollution and will be at best a short-term solution to the emission of GHGs and other gases. However, advanced ICEs offer a good potential to become transitional vehicles before a more sustainable alternative can be implemented. Thus, it is appropriate to discuss the main components that will, with improvements and modifications, allow the ICE to become more environmentally sustainable.

The components can be broken down into 5 main options, where the first four are directed at increasing fuel efficiency, and the final component acts to directly reduce emissions.

1. Advanced engines

The engine is the heart of a vehicle and is the driving force behind propulsion. Subsequently, if engines can be developed and manufactured so that they produce more propulsion with less fuel required, then the emission levels will be lower as well. For example, Compression Ignition Direct Injection (CIDI) engines directly inject fuel into the combustion chamber, thus increasing thermal and overall fuel efficiency (U.S. Department of Energy, 2000). Furthermore, these engines ignite the fuel solely due to compression and deliver up to about three times the fuel economy of today's vehicles (U.S. Department of Energy, 2000). Other engines that are under extensive research are the Spark Ignition Direct Injection (SIDI) Engines. These engines use the same properties as the CIDI to achieve increased efficiency. However, they use a spark to ignite the fuel such as conventional engines used currently. The advantage of these systems, over the CIDI, would be simply that they are closely related to the current ones, thus decreasing the cost of ownership if the vehicle requires maintenance.

Furthermore, the direct injection system atomizes the fuel into a very fine mist in the combustion chamber, which allows for a process that reduces heat loss, softens the combustion process, and increases fuel efficiency (U.S. Department of Energy, 2000).

Other engine types that deserve mention and are currently being researched to be placed into future advanced ICEs are the Stirling Engine, and the Gas Turbine Engine. Both of these are also candidates to become the next generation of super efficient vehicles. Nonetheless, there are many technical barriers to be overcome before any of the aforementioned engine types play a major role in automobile manufacturing.

2. Light Weight Materials

Another way to improve the efficiency of a vehicle is to reduce the weight so that the engine does not have to use as much energy to propel the vehicle. Thus, reducing weight conserves energy, which reduces fuel consumption and diminishes emission output. About 75% of vehicle fuel consumption is directly related to factors associated with weight, thus making lightweight materials critical to the development of highly efficient ICEs (Europa, 2000). Materials such as aluminum, plastics, and advanced composites are all being considered as possible substitutions to currently used steel. For example, carbon fibres are one of the lightest materials that are available on the market. Furthermore, many advanced composites materials are more durable, chemical resistant, and have enhanced structural properties (Europa, 2000). In terms of plastics, many plastic suppliers have developed fluoroplastics that have excellent chemical, mechanical, and thermal properties. These will most likely replace conventional plastics, metals, and other materials that are used for structural or operational purposes.

3. Spark Ignition Technologies

Spark ignition engines are critically dependent on repeatable, reliable ignition to produce good performance and minimize emissions (Dale *et al.*, 1997). Conventional systems produce a sufficient spark at a selected time to produce adequate combustion, but with also modest amount of exhausts (Dale *et al.*, 1997). Enhanced ignition systems would provide higher energies resulting in increased combustion efficiency. Many pollutants, such as carbon monoxide, result from incomplete combustion; therefore a high-energy spark system would result in lower levels of such chemicals.

4. Improved Sensors

Sensors that measure and help to control exhaust emissions have become increasingly important components to the engine system. Oxygen sensors monitor the air/fuel ratio, which helps improve engine efficiency and gas mileage (U.S. Department of Energy, 2000). This is accomplished through ignition timing. If the combustion of the fuel is not timed sufficiently then the fuel could result in incomplete combustion (U.S. Department of Energy, 2000). In turn, the gases emitted by the engine will contain more chemicals such as CO and various NOx varieties. Exhaust flow sensors are also important in determining the amount of pollutants being emitted, such as NOx, CO, or HCs. The integration of oxygen sensors and emission sensors would result in a vehicle that will have increased fuel efficiency, therefore reduced emissions.

5. Catalytic Converters

The commercialization of the catalytic converter has led to a greater reduction in vehicle emissions than any other innovation (U.S. Department of Energy, 2000). The main purpose of catalytic converters is to convert harmful vehicle emissions to compounds that are more environmentally friendly. For example, converters simultaneously convert high percentages of carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx) into less harmful by-products. This is accomplished by the presence of a catalyst inside the converter that triggers a reaction under regular atmospheric conditions. Various oxides of nitrogen, that are inherently GHGs, can be converted to non-greenhouse forms in the presence of a catalyst. However, catalytic converters work best under high temperatures, thus most emissions occurs when the converter is not hot enough. Extensive research is being performed to produce a converter that either heats up more rapidly or to produce a converter that does not require such extreme thermal conditions to work at a maximum performance. Innovations such as compact vacuum insulation allow for increased resistance to heat leakage, thus the converter can reach the optimum temperature more rapidly. A proper thermal management system within a catalytic converter will result in advanced ICEs that have significantly lower levels of emissions (Burch *et al.*, 1996).

Emissions Reductions

There is no question that innovative components that increase efficiency will reduce emissions. However, any combustion engine will emit greenhouse and non-greenhouse gases. Therefore, the search for a present system that will reduce emissions depends upon how large a reduction in emissions is required. In comparison to hybrids, emissions and fuel efficiency will most likely equal, if not surpass, advanced ICEs. Overall, advanced ICEs will significantly reduce emissions, but will not likely have as great of an impact as other alternatives.

Infrastructure

The large portion of the cost in producing advanced ICEs will be for the automobile industry to develop new designs and manufacturing processes. For example, certain materials possess excellent properties that are useful to create lighter, more efficient vehicles; however, many of these materials are currently too expensive to purchase. Furthermore, creating advanced ICEs may lead to the increase in vehicle price, depending on the price of advanced components and innovation of material process development. More than likely, revamping the automotive manufacturing process to assemble advanced ICEs will be less expensive compared to the cost to industry that is necessary for other alternatives such as fuel cells. Since hybrids are currently available and have an existing manufacturing process, it is difficult to compare the costs of potential advanced ICE production and the current hybrid technology. Advanced ICEs would use the existing gasoline infrastructure as well, thus there is virtually no significant infrastructure cost. Overall, it is apparent the costs involved are not nearly as significant as other alternatives considered.

Public Acceptance

The implementation of innovative components and advanced ICEs in general will not require as much incentive as compared to other alternatives, such as in the case of the fuel cell. In fact, the automotive industry is constantly seeking new technologies that are compatible with their current automobile technologies. However, in order for industry to invest more money related to drastic changes in their vehicle design, such as advanced engines, it will more then likely require some incentive to actually manufacture such products. This is mostly do to infrastructure costs with-in the manufacturing system. Furthermore, even though the cost of vehicles may rise, the increase will be minor and most likely will not effect the implementation of advance ICEs. In general, the significance of socio-economic impacts of the implementation of advanced ICEs will not be considerable enough to prevent the success of any new technologies that are compatible with current ICEs, which the automotive industry has interest in marketing.

Long-Term Sustainability

Since ICEs run on gasoline, sustainability is perhaps the biggest disadvantage for advanced ICEs, as compared to other alternatives considered. Gasoline is reformed from fossil fuels and since fossil fuels are a non-renewable resource, then it can be said that advanced ICEs are not sustainable.

5.4.2 Alternatives to Conventional Internal Combustion Engines

5.4.2.1 *Hybrids*

A hybrid car is a vehicle with two different propulsion systems. More specifically, it is the combination of an ICE and an electric motor. Although this technology has been researched since the 1900s, it was only revived in the 1970s and 1980s in conjunction with oil and air pollution concerns. Development has been slow due to the uncertainty of market success (Sperling, 1995). However, most major automobile companies are currently developing their own line of hybrid vehicles.

There are two methods in which ICEs and electric motors can be combined (Figure 9). The first method of combining the two power sources is referred to as a 'series hybrid'. With this method, only the electric motor is directly attached to the transmission. The gasoline engine simply turns a generator, and this generator is able to either charge batteries or power an electric motor. The second method is referred to as a 'parallel hybrid' in which both systems of energy can provide power at the same time with two independent connections to the transmission (Sperling, 1995).

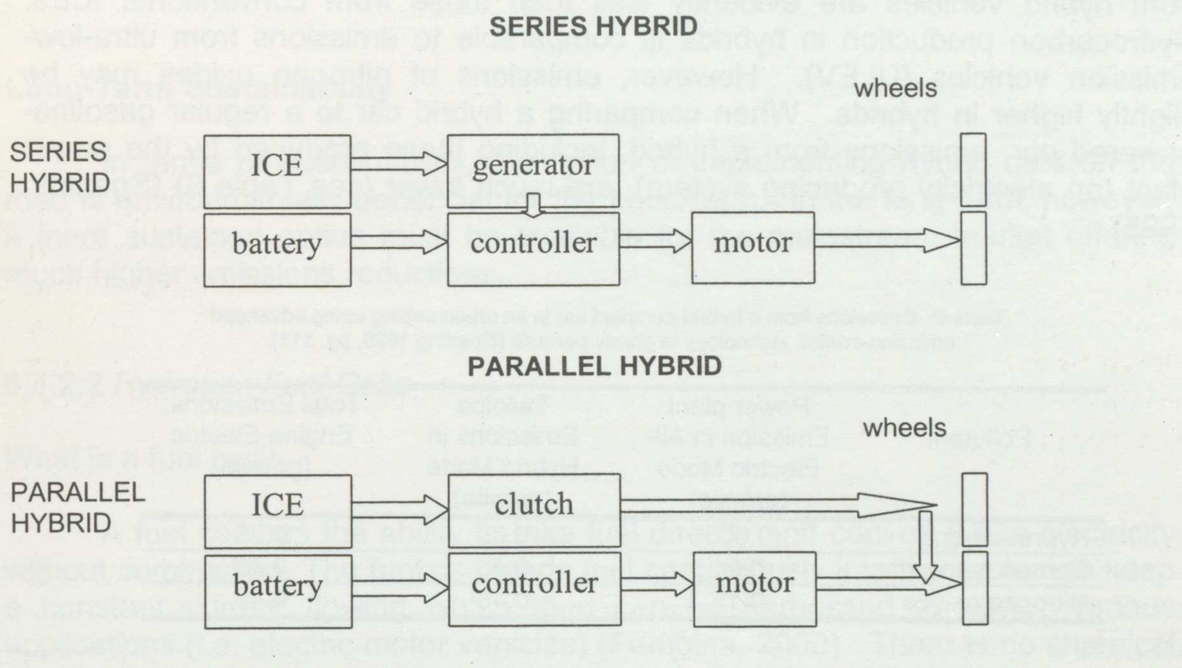


Figure 9: Schematic drawing of series and parallel hybrid configurations (Sperling, 1995).

Honda and Toyota, two automobile companies currently selling a hybrid car line, have taken different approaches in constructing a hybrid vehicle. Honda's version of the hybrid vehicle consists of an electric motor which has a lightweight nickel-metal hydride battery power source located in the rear of the car. This battery is provided energy through regenerative braking. This is achieved by harnessing kinetic energy derived from the forward momentum during deceleration, into the electric motor, which also acts as a generator. The Integrator Motor Assist (IMA) power train, which consists of Honda's VTEC-E gasoline engine, a permanent magnet electric motor and a 5-speed manual transmission, has made this new technology possible (HybridCars, 2000).

Toyota has designed a slightly different hybrid gasoline-electric engine than Honda. In the Toyota Hybrid System, the electric motor carries more of the vehicle's duties. The gasoline engine has dual responsibility. It drives the wheels as well as the generator, which then creates electricity for the electric motor or onboard battery. Under normal driving conditions, the electric motor works with the gasoline engine to power the wheels. At high speeds, the battery gives an extra boost and at low speeds the electric engine solely powers the vehicle (HybridCars, 2000)

Emissions Reductions

A variety of benefits and advantages can be derived from hybrid technology. Reduced emissions are one of the main beneficial outcomes of the use of hybrids because it takes advantage of regenerative braking. Therefore, energy can be derived from the forward momentum of the vehicle. Emissions from hybrid vehicles are evidently less than those from conventional ICEs. Hydrocarbon production in hybrids is comparable to emissions from ultra-low-emission vehicles (ULEV). However, emissions of nitrogen oxides may be slightly higher in hybrids. When comparing a hybrid car to a regular gasoline-powered car, emissions from a hybrid, including those produced by the power plant (an electricity producing system), are much lower (see Table 6) (Sperling, 1995).

Table 6: Emissions from a hybrid compact car in an urban setting using advanced emission-control technology in grams per mile (Sperling 1995, pg. 111).

Pollutant	Power plant Emission in All-Electric Mode (gr/mile)	Tailpipe Emissions in Hybrid Mode (gr/mile)	Total Emissions, Engine-Electric (gr/mile)
Hydrocarbons	0.005	0.05	0.05
Carbon monoxide	0.04	0.45	0.45
Nitrogen oxides	0.15	0.46	0.46

Infrastructure

Hybrid vehicles require no additional infrastructure for implementation into mainstream use. The technology has been researched and developed for decades and is currently available to the public and to industry (Sperling, 1995).

Public Acceptance

Hybrids have a slightly higher ticket price when compared to other new vehicles of similar size and power. The price can be up to $9000 (CAD) more than a manufacturer's other basic compact car. The Honda Insight sells for approximately $27,000 (CAD) and the Toyota Prius sells for approximately

$29,000 (CAD). However, because of the combination of gasoline and electricity, fuel costs are much lower in a hybrid than in an internal combustion engine (Toyota Canada and Honda Canada, 2001). It takes much less fuel in a hybrid to travel the same distance as in a regular gasoline model (see Table 7). The hybrid car offers similar features as a conventional gasoline vehicle. Performance on the road is comparable, if not better than other compact vehicles (Hermance and Sasaki, 1998).

Table 7: Fuel economy for Toyota Prius hybrid and a comparable ICE (Hermance and Sasaki, 1998).

	Average Speed (km/h)	Toyota Prius Hybrid	ICE
Fuel Economy (L/100km)			
City driving	48.2	4.9	7.6
Highway driving	77	4.4	6.5

Long-Term Sustainability

In terms of sustainability, the option of implementing hybrid cars on the road is environmentally beneficial for the short-term. In the long-term, however, a more sustained option must be available for the mainstream market offering much higher emissions reductions.

5.4.2.2 *Hydrogen Fuel Cells*

What is a fuel cell?

A fuel cell has the ability to take fuel directly and convert it into electricity without combustion. The fuel cell feeds fuel continuously into the system to keep a constant current flowing which then can be harnessed to power various applications (i.e. electric motor vehicles) (Pembina, 2000). There is no chemical combustion in the process, so in theory a perfect fuel cell will produce zero emissions. Furthermore, a fuel cell has no moving parts, thus noise pollution is minimal and the electricity liberated is used very efficiently (Billings and Sanchez, 1994).

The basic structure of a fuel cell consists of an anode, a cathode, and an electrolyte that separates the two electrodes. Hydrogen flows into the anode where it dissociates in the presence of a catalyst, creating hydrogen ions and donating electrons to the anode (see Figure 10) (Billings and Sanchez, 1994).

$$\text{Anode reaction:} \quad H_2 \Rightarrow 2H^+ + 2e^-$$

Simultaneously, oxygen is being supplied to the cathode, so hydrogen ions pass through the electrolyte (an ion conductive substance) to react with oxygen at the cathode (Billings and Sanchez, 1994). The current created by the dissociation of elemental hydrogen into ions travels up through the anode, through the load (i.e. electrical motor), and then back to the cathode where it participates in the hydrogen-oxygen reaction (Billings and Sanchez, 1994).

$$\text{Cathode reaction:} \quad 2H^+ + 2e^- + 1/2O_2 \Rightarrow H_2O$$

Thus, oxygen, hydrogen, and the returning electrons react to form water. Therefore, the only byproduct in an ideal fuel cell system is water, and some nitrogen.

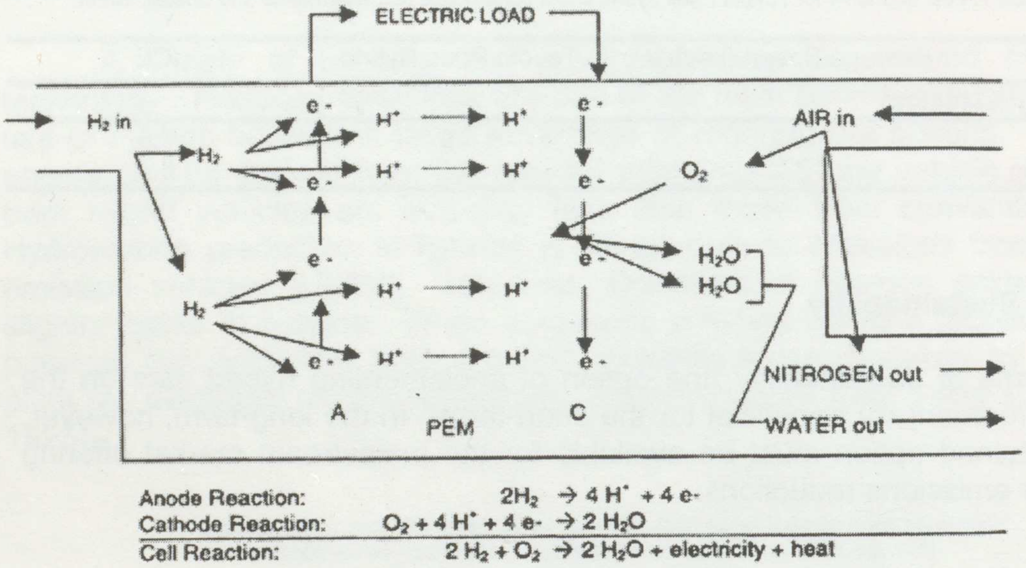


Figure 10: Fundamental schematic diagram of a fuel cell outlining the basic function and structure (Pembina, 2000).

Where does hydrogen come from?

Hydrogen can be produced from a number of sources and processes: steam methane reforming (i.e. natural gas reforming), electrolysis of water, reforming of gasoline, steam reforming of methanol, and partial oxidation of heavy oil. Due to cost and environmental constraints the latter will be disregarded in this report. The others exhibit a much greater potential to become the main supplier of hydrogen because they are processes that will establish significantly lower levels of emissions. In other words, the production of hydrogen itself can produce significant levels of emissions, so choosing a process that will keep those emissions to a minimum is desired.

It is often said by analysts that the main concern of the introduction of the fuel cell is not the fuel cell itself, but how the energy source (hydrogen) will be manufactured, delivered, and stored (Pembina, 2000). There are three main strategies for producing, distributing, and storing hydrogen (Pembina, 2000):

1) Hydrogen can be processed in large centralized industrial units and distributed via pipelines or trucks to fuelling stations. This is similar to current infrastructure for gasoline stations and refinery industries.

2) Hydrogen can be produced at a large number of small, decentralized processors (i.e. produced and delivered at the fuelling stations).

3) Fuel processors can be located directly on-board the vehicle, and convert fuels such as methanol, gasoline, or ethanol into hydrogen. Thus, this option could make use of the existing infrastructure by using gasoline as the fuel that consumers would put into their vehicles.

Hydrogen production and distribution systems, representing the different types of Fuel Cell Vehicles (FCVs), are listed in Table 8. Different technology options are considered for three main hydrogen strategies: on-board reforming, centralized production, or decentralized production.

Table 8: Hydrogen production and distribution systems to be included in the criteria analysis.

Name of System	Description of System	Reason for Inclusion
On-board Reformulated Gasoline Fuel Processing	• FCV w/ on-board fuel processor extracting hydrogen from gasoline for direct use. • No hydrogen storage required.	• Extensive research in the area of gasoline processors. • Uses existing infrastructure. • Technology available.
Centralized Methane Reforming	• Produce hydrogen w/ large-scale steam methane reformers. • Distribution via pipelines. • Hydrogen stored on-board vehicle and at filling station.	• Well-established technology for producing hydrogen. • Use of natural gas infrastructure.
Decentralized Methane Reforming	• Hydrogen produced by a number of smaller scaled reformers. • Hydrogen stored on-board the vehicle.	• Use of natural gas infrastructure. • Technology exists.
Decentralized Electrolysis	• Hydrogen is produced at a number of smaller scaled facilities through electrolysis of water. • Hydrogen stored on-board the vehicle.	• Utilizes electricity infrastructure. • Electrolysis technology exists. • Lowest in terms of emissions.
On-board Methanol Reforming	• FCV w/ on-board processor that extracts hydrogen from methanol for direct use. • No hydrogen storage required.	• Extensive research in this area. • Technology exists.

Due to the limited scope of this report, a select number of hydrogen systems will be considered or evaluated. However, the options not considered (Table 9) must not be forgotten. In the future, different factors may influence the practicality of those hydrogen systems.

Table 9: Hydrogen systems, which are not included in the criteria analysis.

Name of system	Description of system	Reason for exclusion
Centralized Electrolysis of water	• Large-scale production of hydrogen through the electrolysis of water. • Hydrogen shipped to filling stations.	• A centralized facility would require vast amounts of electricity. • Current electricity is supplied through the combustion of fossil fuels, which is counter-productive in the task of reducing emissions. • Nuclear power is also considered as an environmentally unacceptable option. • Not a sustainable option until electricity generation becomes more efficient itself.
On-board electrolysis of water	• Production of hydrogen for direct use, through the electrolysis of water on-board the FCV. • Input is water and output is water, essentially no pollution.	• Technology currently not efficient for large-scale production. • However, often quoted as most sustainable transportation alternative when technology arrives.
Biomass power	• Centralized production of hydrogen from methane acquired from biomass, livestock waste, feedstocks, and landfills.	• Production unlikely able to support the large methane demand in the long-term. • Environmentally sustainable, but not economically and socially sustainable.
Centralized gasoline reforming	• Centralized reforming of gasoline to produce hydrogen. • Hydrogen shipped to filling stations.	• Not efficient to produce hydrogen at centralized stations as compared to on-board processors. • Gasoline is not a sustainable option, however if it is going to be used it is sensible to use the existing infrastructure i.e. on-board reforming of gasoline.
Decentralized gasoline reforming	• Decentralized reforming of gasoline at smaller scale facilities. • Hydrogen produced at filling stations.	• Similar reasons as for centralized reforming. • More efficient to make use of existing infrastructure.

Emissions Reductions

Some emissions from the following FCVs are summarized in Table 10, below.

On-board Reformulated Gasoline Powered-FCV:

This FCV has the potential to produce about 22% less GHGs when compared to the conventional ICE (Pembina, 2000). The main source of emissions comes from the on-board reformer that extracts of hydrogen from the gasoline (Pembina, 2000). The fuel cell itself produces virtually no emissions.

On-board Reformation of Methanol-FCV:

As compared to an on-board reformation of gasoline FCV, the analogous methanol system produces about 16% less GHGs (Pembina, 2000). This is most likely due to the fuel source, methanol. The reformation of methanol produces similar emissions as the reformation of gasoline but in significantly lower concentrations (Pembina, 2000).

Centralized Hydrogen Production from Methane Reformation:

This system reduces emissions by about 72% as compared to the conventional ICE system (Pembina, 2000). This includes the emissions resulting from the methane reforming plant and from processing and reformulating gasoline (Pembina, 2000). However, the methane reforming plant may affect the nearby residential areas and be a source of local air pollution (Pembina, 2000).

Decentralized hydrogen production from methane reformation:

This system also has a large reduction of overall emissions of about 70% as compared to the conventional ICE. However, the reduction is not quite as large as the centralized system. This is mostly due to the fact that large centralized facilities have an increased ability to produce in bulk with greater efficiency, thus the overall emissions of the plant would be lower (Pembina, 2000). The vehicle itself will produce no emissions as in the case of centralized hydrogen production. In effect, the vehicle used in this process will be the same as in the case of centralized production. Thus, the difference in emissions, between centralized and decentralized, is solely due too the production and delivery of hydrogen to the FCV.

Decentralized hydrogen production by the electrolysis of water:

This system will have the highest level of emissions of all systems considered, however it still reduces emissions by about 5% as compared to the conventional ICE (Pembina, 2000). This system is the greatest polluter because of the excessive amounts of electricity required to produce hydrogen through electrolysis. Electricity is currently produced mainly by the combustion of fossil fuels; therefore the amount of emissions produced would be greater than any of the above options.

Table 10: Estimated local emissions for FCV's compared to conventional gasoline vehicles and proposed or actual emissions standards (g/mile)(Thomas *et al.*, 2000).

Vehicle Type	VOCs (g/mile)	CO (g/mile)	NOx (g/mile)
Gasoline ICE	**0.755**	**7.553**	**0.704**
Hydrogen FCV	**0.004**	**0.003**	**0.001**
Methanol FCV	**0.023**	**0.004**	**0.001**
Gasoline FCV	**0.371**	**0.005**	**0.001**
Emission Standards (g/mile)			
Tier II	**0.125**	**1.7**	**0.2**
ULEV	**0.04**	**1.7**	**0.2**
SULEV	**0.01**	**1.0**	**0.02**
EZEV	**0.004**	**0.17**	**0.02**

ULEV – Ultra Low Emission Vehicle, SULEV – Super Ultra Low Emission Vehicle, EZEV – Essentially Zero Emission Vehicle.

Infrastructure

Small scale methanol reformers or electrolysers at local fuelling stations would avoid the expensive pipeline or hydrogen tankers that would be required to ship the hydrogen otherwise. The existing infrastructure could be put into use through the electrical power grid and the natural gas pipeline system for FCV refuelling (Thomas *et al.*, 2000). Thus, the current infrastructure system would be the backbone of the hydrogen infrastructure system. Similarly, on-board processors that convert methanol or gasoline would use the current infrastructure much the same way as small-scale reformers or electrolysers. Gasoline would be provided the same way as it is today; except that vehicles would operate on fuel cell technology.

If FCVs have increased demand, other options may be more practical, such as building a hydrogen pipeline system. The pursuit of such an option is very much dependant on the existence of willing investors that will support and uphold the hydrogen infrastructure.

When considering infrastructure issue, it is important to determine whether it is more cost effective to implement the on-board fuel processor option or the small-scale fuel processor at filling stations. Thomas *et al.* (2000) estimated the additional cost per vehicle, in addition to conventional hydrogen fuelled FCVs, of small-scale methane reformers and on-board methanol reformers. The estimated cost per vehicle for the small-scale methane reformer is about $380/vehicle and the estimated cost for an on-board methanol reformer option is about $450/vehicle. The study assumes that there are 1000 vehicles being supplied by the filling station.

Public Acceptance

The most cost effective, and therefore more popular, hydrogen-based transportation system will be the one with the fewest technical challenges (Thomas *et al.*, 2000). The more complex the vehicle produced, the more money will be required to manufacture and maintain the vehicle.

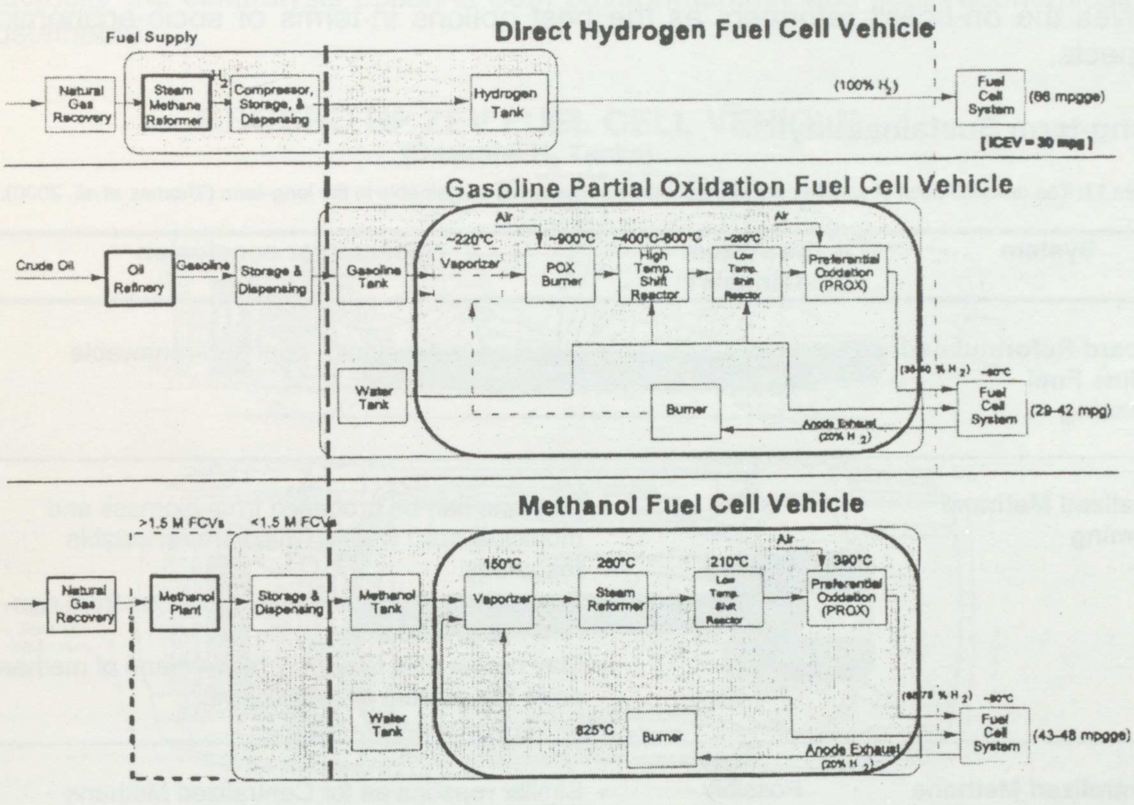


Figure 11: Flow diagram representing the complexity of each fuel cell system option (Thomas *et al.*, 2000).

The methanol and gasoline-run FCVs will cost more because those systems are much more complex as compared to the basic hydrogen FCV. Therefore, the FCV that will be cheapest to produce is hydrogen fuelled because no additional components will be required to process the fuel before interacting with the fuel cell itself. Between the methanol and gasoline fuel processors, the gasoline fuel processor is considered to be more complex (Figure 11). Under the assumption that increased complexity will increase manufacturing costs, the cheapest to most expensive FCVs are hydrogen, methanol, and gasoline-fuelled.

The implementation of such a technology as hydrogen fuel cells will require investment by both society and industry. It is evident that problems will arise when dealing with required investments. For example, the hydrogen industry will not want to invest in hydrogen fuel cell technology and infrastructure unless there is a sufficient demand for FCVs to provide a return on investment. Similarly, the automobile industry will not want to invest in FCV manufacturing unless there is a sufficient infrastructure in place in order to fuel those vehicles. Therefore, the potential for fuel cell technology to become popular depends on public demand. The introduction of fuel cell technology incrementally could help to gain appeal. Such an approach could begin with on-board reformers, then move to small-scale hydrogen producers, and finally a complete hydrogen infrastructure. Thus, presently the most practical solution would be to use on-board processors of either gasoline or methanol. However, this would require the investment of vehicle consumers who would have to pay a few thousand dollars extra for the added fuel processor (Thomas *et al.*, 2000). Overall, the centralized or the decentralized options are not the most practical at the present time. This leaves the on-board reformers as the best options in-terms of socio-economic impacts.

Long-term Sustainability

Table 11: The determination of whether a s pecific hydrogen system is sustainable in the long-term (Thomas *et al.*, 2000).

System	Is the system sustainable?	Reasons for conclusion
On-board Reformulated Gasoline Fuel Processing	No	• Gasoline is developed from non-renewable resources.
Centralized Methane Reforming	Possibly	• Methane can be produced from biomass and municipal solid waste, which are renewable resources. • Currently methane is mostly produced from non-renewable resources. • May not be able to supply the demand of methane once this system is established.
Decentralized Methane Reforming	Possibly	• Similar reasons as for Centralized Methane Reforming.
Decentralized Electrolysis	Possibly	• Electrolysis using electricity generated from hydro, wind, or solar powers would be sustainable. • Currently, most of the electricity produced is from fossil fuels or nuclear power, which both rely on non-renewable resources.
On-board Methanol Reforming	Possibly	• Methanol can be produced from biomass or municipal solid waste, which are renewable resources. • May or may not be able to meet the methanol demands once the hydrogen system has been established.

From the options evaluated in Table 11 it is evident that gasoline is a non-sustainable option and should only be considered as a transitional system until a truly sustainable fuel cell system is implemented. The greatest potential for a hydrogen system to be truly sustainable is through the electrolysis of water, creating hydrogen and oxygen as the byproducts. However, currently the electricity grid is heavily dependant on fossil fuel and nuclear power, so using vast amounts of electricity would be counter-productive in the overall goal of reducing emissions. Nonetheless, in areas that rely on hydro, wind or solar electricity the electrolysis option is both environmentally and socio-economically sustainable.

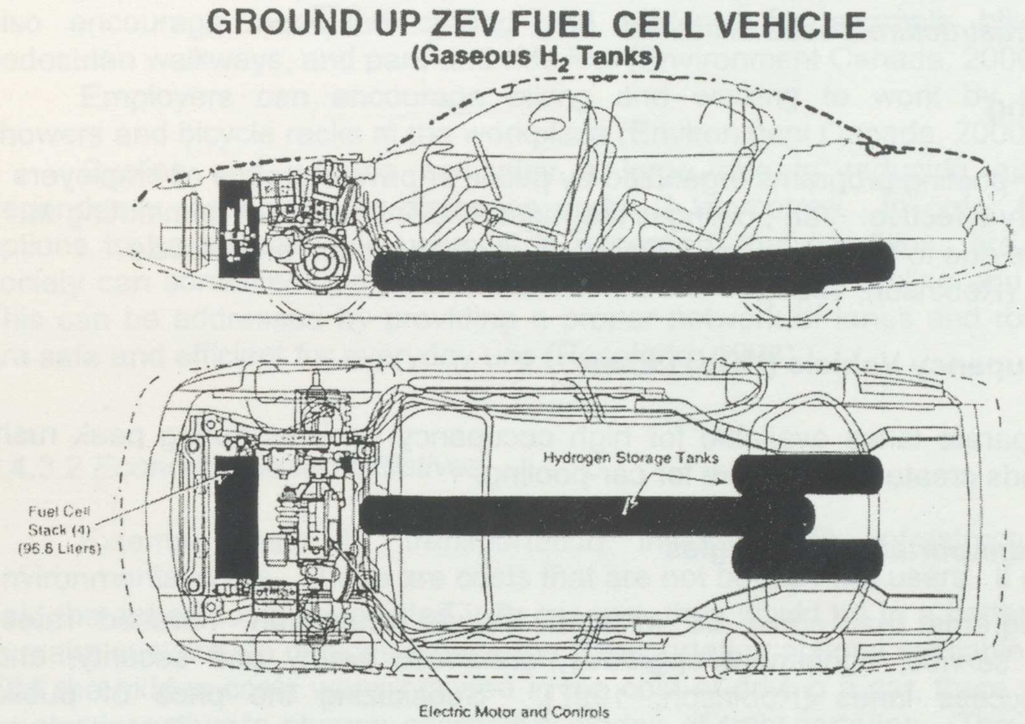


Figure 12: Diagram showing important components of hydrogen Fuel Cell Vehicles (Thomas *et al.*, 2000).

Based on the criteria evaluated, the best option is the on-board methane FCV system. Although methane reformation does emit some pollutants, the level of atmospheric degradation is not as significant as others considered here. In terms of cost, the on-board methane reformer will be greater per vehicle in comparison to the simple hydrogen fuelled vehicle (Figure 12) due to complexity. However, the methane option will make use of the current natural gas infrastructure, therefore this option is much cheaper than the hydrogen fuel option which would require a massive upheaval in infrastructure. Thus presently, the most practical fuel cell option will be the on-board methane reformer FCV when determining the best transportation strategy for the year 2015 and beyond.

5.4.3 Reducing Automobile Dependency

Transportation systems in Canada currently depend on an unsustainable use of non-renewable resources and are resulting in adverse impacts to the biophysical environment. The dominant land transportation systems in Canada are designed for and encourage the use of the private automobile (Jay, 1998). A transportation strategy must stress the reduction of single occupancy vehicles as the only sound way to achieve a reduction in greenhouse gas emissions, improved air quality, reduced energy consumption, and a relief in traffic congestion (Roseland, 1998). The following initiatives are designed to reduce the dependency on single occupancy vehicles.

5.4.3.1 *Infrastructure-Based Initiatives*

Car Pooling

Car-pooling programs organized by public or private groups or employers can be very effective. Van-pooling is the most efficient means of commuting at peak hours due to the high occupancy per fuel consumption and vehicle emissions (Robinson, 1997).

High Occupancy Vehicle (HOV) Lanes

Separate lanes available for high occupancy vehicles during peak rush hour periods create an incentive for car-pooling.

Public Transportation Strategies

Programs that could be initiated include promotion, reduced rates, extended service, equipment upgrades, enhanced safety and security, and special access lanes (Robinson, 1997). Subsidizing the price of public transportation is an option and would provide a large incentive for Canadians to include this mode of travel in their daily lives.

Community Planning

Higher urban densities, smaller communities, and improved quality of neighbourhoods all tend to lower rates of transportation use. Community planning can help to improve the efficiency of public transportation systems. High urban concentration or pockets of high-density development can also help to make public transportation more efficient (Jay, 1998).

The increased use of the private automobile has encouraged the spread of urban areas, resulting in urban sprawl. The form of urban growth must be redirected by encouraging greater densities of housing around significant centres of work and reinforcing suburban centres as local service centres (Jay, 1998).

Canadian communities should aim to become more public transport oriented. Together with higher density development and mixed lane uses, communities can wean their dependence on the private automobile.

Bicycle and Pedestrian Programs

In order to facilitate these modes of transportation, the design and physical shape of the street system must accommodate for cyclists and pedestrians. The restriction of cars could be considered for residential, shopping, and school districts where cyclists and pedestrians could be given the right-of-way (Jay, 1998).

Improvements in the integration of different modes of transportation would also encourage increased cycling and walking, for example bike racks, pedestrian walkways, and park-and-ride lots (Environment Canada, 2000a).

Employers can encourage biking and walking to work by providing showers and bicycle racks at the workplace (Environment Canada, 2000a).

Cycling and walking can play a large role in reducing automobile dependency, especially for distances under 2 kilometres. In order for these options to be appealing to users, it is necessary that conditions are safe, as society can sometimes perceive main roads as unsafe for cycling and walking. This can be addressed by providing a proper network of lanes and routes that are safe and efficient for everyday use (Roseland, 1998).

5.4.3.2 *Economic-Based Initiatives*

External costs to transportation include both infrastructure and environmental costs. These are costs that are not born by the users. If motorists paid the actual costs associated with car use, they would be in a better position to make sustainable choices among the transportation options available to them. If all the hidden costs were included in the cost of driving a car, there would be greater incentive to choose alternative modes of transportation. The following initiatives attempt to internalize some of these external costs.

Road-pricing

Examples of road-pricing strategies include charging a toll for single occupancy vehicles or a toll to enter the downtown core during high-peak traffic periods (Environment Canada, 2000a).

Parking Management

A reduction in the availability of public car parking and employer-subsidized parking (Environment Canada, 2000a) or an increase in the cost of car parking within the city centre (Jay, 1998) will the deter the use of the private car and increase the use of public transportation systems. In addition, less expensive parking for those who carpool is an option that can be offered to commuters by city planners (Environment Canada, 2000a).

Adjustments to Current Taxes and Fees

Higher gasoline taxes would better reflect the cost of providing transportation infrastructure as well as the costs in terms of impacts to the biophysical environment. Alternative options include charging surtaxes to those purchasing a second car. An increase in land tax would better reflect the increased cost of providing transportation to outlying areas and would encourage settlement in the city core, where the car is needed less, thus discouraging urban sprawl (Environment Canada, 2000a).

5.4.3.3 *Employer-Based Initiatives*

Alternative Work Hours

Modification of work hours to reduce peak travel demand, or reducing the number of working days per week to reduce the overall need for travel are two possible initiatives that could be implemented by employers (Robinson, 1997). This would decrease traffic congestion, which is a large contributor to vehicle emissions in the city core.

Tele-commuting

Current technologies have the ability to permit many would-be commuters to work from home or from satellite offices, thus reducing the need for intercity travel (Robinson, 1997).

5.4.3.4 *Public Education and Outreach*

Education and Promotion

The implementation of any of the above initiatives may result in major political opposition and public disapproval. Widespread community promotion, education, and consultation are necessary to promote public acceptance and political agreement. Changes must be introduced slowly and incrementally and the community must be involved in the decision-making process (Jay, 1998).

2. How willing would you be to take each of the following actions to reduce vehicle air pollution in your area?

See Table 12 for a summary of the results to this question.

a. Use public transit twice a week more than you do now

28% of those surveyed feel that it is not possible to use public transit.

b. Walk or cycle instead of driving for two or more of your shorter trips each week.

35% of respondents are definitely willing to walk or cycle instead of driving for two or more of their shorter trips each week.

c. Share a ride with others twice a week more than you do now

32% said that they were definitely willing to share a ride twice a week more than they do now.

d. Keep car better tuned and purchase most efficient vehicle possible to meet your needs

34% said that they were definitely willing to keep their cars better tuned and purchase more efficient vehicles, and 30% are doing it as much as possible already.

e. Make walking, biking or using public transit a part of your trip to work

The responses were divided for this question: 27% said they were already doing it as much as possible while, 32% said that it was not possible to use public transit.

f. Chain your trips (2 or more together) to the grocery store, recreational facilities and other public or retail services

Almost 50% of respondents said that they were already chaining their trips as much as possible.

Table 12: Responses to question 2

Choice – see above for questions	a	b	c	d	e	f
	Percentages					
0 – did not answer	3.0	1.0	3.0	5.0	2.0	3.0
1 – definitely willing	19.0	35.0	32.0	34.0	13.0	30.0
2 – somewhat willing	18.0	20.0	25.0	22.0	21.0	10.0
3 – not at all willing	12.0	7.0	7.0	6.0	5.0	6.0
4 – not possible	28.0	15.0	17.0	3.0	32.0	2.0
5 – already doing it as much as possible	20.0	22.0	16.0	30.0	27.0	49.0

3. Approximately how many kilometres do you drive each week? How many kilometres could be saved, realistically, by undertaking some of the measures above?

The results ranged from 0 km to 1000 km driven each week with an average of approximately 150 km. Those surveyed said that they could realistically reduce their use, on average, by 20 km each week.

22% drove 0 km each week, 20% could not reduce their car use at all, 23% could reduce their car use by 20% (+/- 5%), and 4% could realistically eliminate all their car use each week.

4. What keeps you from reducing your car use further?

26% stated that there is a lack (or none) of public transportation or alternatives in their area.
26% stated convenience, time, efficiency, or comfort of a car as reasons for not reducing their use.
13% say that the weather is the major constraint to reducing their car use.
23% were unable to answer this question because they don't own a car.

5. What are the two most important reasons that would prompt you to reduce your car use (Figure 13)?

Top Four Reasons:

Expense/cost/economic/maintenance costs:	15.5%
Increased gas prices:	12.5%
Increased availability of public transportation:	12%
Environment/Air Pollution:	8%

Other reasons include: Change jobs/move (6%), exercise/health (7%), change in urban structure (i.e. centralized, closer to residential areas) (2%), bad road conditions/weather (3%), traffic congestion (2.5%), fuel shortage (2%), availability of car pool (1.5%), and accidents (1.5%).

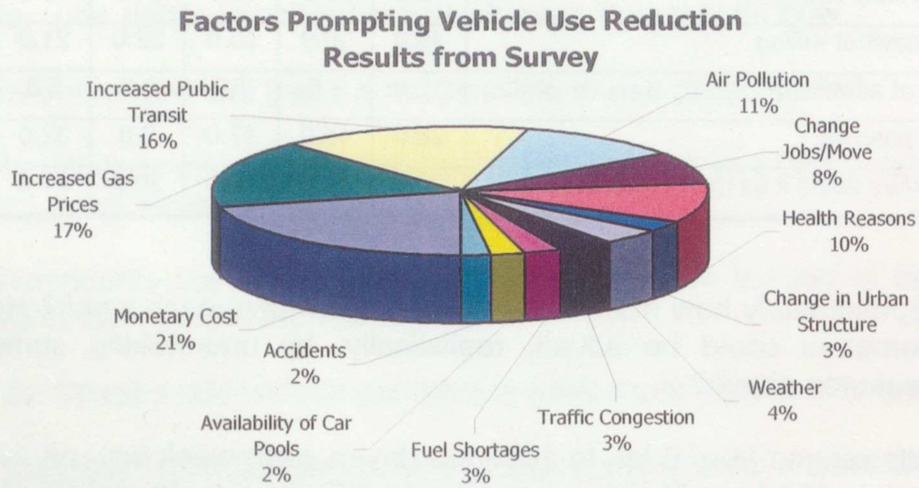


Figure 13: Factors Prompting Vehicle Use Reduction – from Survey Question 5.

6. The transportation system has many different external costs. Which are of most concern to you (Table 13)?

Table 13: Responses to most important external costs of the transportation system.

road construction/maintenance	32%	health	46%
inefficient land use/foregone land use	33%	noise pollution	26%
space use for parking	16%	air pollution	80%
non-renewable fuel consumption	47%	climate change	32%
disruption of existing communities	20%	accidents	44%

7. If you had the power to make decisions for the country and you wanted to reduce the cost of the transportation system, which of the following options would you pursue (Table 14)?

Table 14: Responses to most important options for reducing the cost of the transportation system.

provide incentives for car owners to reduce use	65%
increase the price of gasoline dramatically	14%
offer insurance breaks to drivers who car pool	46%
increase price of city center parking	16%
require vehicle owners to have their cars and trucks pass an annual vehicle and emission inspection, with a penalty for those who fail to meet standards	55%
start a gas-guzzler tax – an extra tax paid by purchasers of less fuel-efficient new vehicles	48%
start road pricing – an extra charge paid to allow drivers to travel in certain areas during rush hour	14%
introduce exclusive lanes for cycling, buses and better facilities or pedestrians	79%
zoning changes to favour mixed use	19%

8. What changes to your public transit system would prompt you to use it more?

Suggestions included:

Increased Efficiency	29% of those surveyed
Increased Coverage	19%
Initiate Public Transportation in their area	14%
Lower Costs	12%
Increased Connections Between Cities	11%
Increased Reliability	11%
Increased Efficiency	9%
Cleaner/Safer	6%
Less Overcrowding	5%
Nothing (includes, "it's fine", "no comment", or "Nothing would make me use Public Transit")	25%

9. If you could change three things about your community to allow you to use your car less often, what would they be?

Top 3 Changes

1. Increased Public Transportation (reliability, frequency, coverage, efficiency)	39%
2. Bicycle Lanes (more, better, safer)	36%
3. Changes to Urban Planning/Zoning	27%

Other Suggestions

More, Better, Safer Walking Trails and Sidewalks (19%), Rail/Increased Transportation between cities (18%), Fewer Roads/Less Vehicles (5%), Introduce Public Transportation to Community (5%), More Efficient Vehicles (4%), Changes to Public Perceptions/Attitudes (3%), Incentives for Car Pooling (3%), Financial Incentives (2%).

What is your driving profile?

1. How many cars does your household own (Table 15)?

Table 15: Number of cars per household of those surveyed.

number of cars/household	%
0	11
1	22
2	43
3	24

2. How often do you use your car with only yourself and no passengers?

all the time	6%	most of the time	45%
not very often	29%	none of the time	13%

3. List the three places you usually visit most during the week, the distance from your home and how you get there (walk, bike, bus, train, carpool, car, etc.) (Table 16)

Table 16: Places most often visited each week, distance traveled, and method.

Where	% of People Surveyed	Average Distance Traveled (km)	Max Distance Traveled (km)	Min Distance Traveled (km)	Method of Transportation
work	20%	20.1	125	1	car – 71.0% walk – 17.4% transit – 5.8% bicycle – 4.3% carpool – 1.4%
school	15.7%	4.3	20	1	car – 30.6% walk – 19.4% transit – 38.7% bicycle – 11.3%
shopping	13.7%	9.8	50	1	car – 80.9% walk – 14.3% transit – 4.8%
friends	10.7%	25	200	1	car – 78.4% walk – 8.1% transit – 13.5%
groceries	10.7%	3.8	12	1	car – 63.9% walk – 13.9% transit – 8.3% bicycle – 2.8% taxi – 5.6% carpool – 5.5%
recreation	9.7%	26.4	200	1	car – 44.4% walk – 33.3% transit – 11.1% bicycle – 8.4% carpool – 2.8%
downtown	3.3%	3.3	7	1	car – 18.8% walk – 43.7% transit – 25% taxi – 12.5%
church	1.7%	10.2	23	4	car – 100%
other	14.5%				car – 62.1% walk – 18.4% transit – 9.8% bicycle – 9.7%

5.4.3.6 Criteria Analysis

The above list of initiatives is by no means an exhaustive one and incurring only selective measures is not sufficient in a transportation strategy. A holistic approach is necessary, by incorporating infrastructure-based initiatives and economic incentives with public education and outreach. Although reducing automobile dependency will be assessed as an alternative against the aforementioned criteria, it is assumed that this alternative will be implemented complimentary to one or more of the technological alternatives presented earlier.

Emissions Reductions

The following emission reductions in CO_2 equivalents are projections based on full implementation of the following initiatives across Canada (Transport Canada, 1999):

Table 17: Emission reductions in CO_2 equivalent from selective reduction in automobile dependency initiatives (Transport Canada, 1999).

Initiative	Reduction in CO_2 Equivalent (million tonnes)
Public education and outreach	3.7
Public transportation, bicycle and pedestrian programs	10.1
HOV lanes and improved traffic flow	1.5

While it remains difficult to quantify the reduction in emissions from initiatives to reduce automobile dependency, it is evident that choosing to walk, cycle, or use public transportation over the private automobile will dramatically reduce vehicle emissions.

Infrastructure

Costs of implementing any of the above initiatives may be either consumer-oriented or government-oriented. The consumer-oriented costs include:

- Rate regulation and/or permits
- Taxes (user and enforcement tax)
- Transit costs
- Parking costs

The government-oriented costs include:

- Provision of bicycle and walking paths
- Education and promotion
- Construction of or improvements to high occupancy vehicle lanes
- Re-zoning of land use patterns
- Provision of public transit – increased efficiency and availability and subsidized costs

It must be taken into account that the associated costs will depend greatly on the degree to which the above initiatives are implemented.

Public Acceptance

In order for any of the above initiatives to be smoothly implemented into society, an overall shift in Canadians' behaviours and lifestyles is required. It will be difficult to aggressively implement any of the above measures due to society's attitude toward continued and increased use of the private automobile. People feel that having an automobile available to use everyday thereby reduces their desire to pursue alternative travel behaviour. However, the growing recognition of air quality and global warming as important environmental issues, acknowledgement that our road systems are reaching their capacity, and global energy shortages have prompted more people to look for alternatives in their modes of transportation (Stewart and Pringle, 1997).

Required Policies

The initiatives suggested above may require extensive policies in order for them to be considered mandatory; current initiatives are based only on voluntary measures. Possible challenges may occur due to the shared jurisdiction of transportation across federal, provincial, and municipal levels. Given the shared responsibility, the result is often a barrier to positive change (Robinson, 1997).

Long-Term Sustainability

Once implemented, the initiatives suggested above will be very sustainable solutions with long lifetimes, due to their decreased dependency on finite resources with minimal environmental impact.

5.5 Multi Criteria Evaluations (MCE)

5.5.1 MCE with equally weighted criteria

Table 18: MCE based on equal weighting of criteria.

	Proposed Alternatives				
Criteria	Criteria Weighting	Alternative Fuels	Advanced Internal Combustion Engine	Hydrogen Fuel Cells	Electric-Gasoline Hybrids
Best Emissions Reductions	0.2	0.6	0.8	0.2	0.4
Least Required Infrastructure	0.2	0.6	0.4	0.8	0.2
Greatest Public Acceptance	0.2	0.6	0.2	0.8	0.4
Least Required Policy	0.2	0.8	0.2	0.6	0.4
Long-term Sustainability	0.2	0.6	0.8	0.2	0.4
Total		3.2	2.4	2.6	**1.8**

A lower number represents an alternative that best fits the required criteria.

Justification of rankings

The four proposed alternatives were ranked based upon researched information and data, which has been presented throughout the report. Under the criterion 'emissions reduction', all proposed alternatives were ranked based on estimates of their emission data (in grams per mile) of hydrocarbons, carbon monoxide and nitrogen oxides, and the impact these technologies would have compared to current technologies.

Evaluating the amount of infrastructure needed in order to put the proposed alternative in place completed ranking for the criterion of 'cost of infrastructure'. The more infrastructures needed, the higher potential costs of the alternative, and therefore the higher ranking the alternative was given. Hybrid technology was ranked as #1 for this criterion due to its low requirements for increased infrastructure. Hydrogen fuel cells were ranked as #4 for this criterion because of their relatively large requirement for large-scale infrastructure.

The 'public acceptance' criterion ranks were determined mainly from relative costs to the consumer. The high emphasis placed on price to the consumer is based on the CAA 1999 survey that found 63.4% of respondents said that price was the most important factor when purchasing a new vehicle (Canadian Automobile Association survey, 1999).

The 'required policy' criterion rankings were based upon an evaluation of currently existing transportation and emission policies in Canada and the relevance for each alternative.

The 'long-term sustainability' criterion refers to 2015 and beyond and attempts to account for the environmental, economic, and social performance of the alternative in the future (Gordon, 1995). Alternatives based on non-renewable resources would not score well under this criterion.

5.5.2 Assumptions

- Public adequately informed
- Long-term refers to 2015 and beyond
- Cost to consumer and cost to producer are independent

5.5.3. MCE with Unequally Weighted Criteria

In reality, each of the criteria is not going to have equal importance in the eyes of decision makers. In order to investigate how changes in the relative importance of different decision making criteria can affect the outcomes of the MCE, two additional unequally weighted MCEs were performed.

Emissions reduction (environmental) and relative cost (economic) criteria are often valued in highly divergent methods. Therefore, in the two MCEs performed, each of these criteria was given dramatically different rankings while all other criteria were held constant. In the high emissions reductions MCE, emissions reductions were given a relatively high weighting of 0.4, whereas economic criteria (cost of infrastructure and public acceptance), were each given a weighting of 0.1. Required policy and long-term sustainability were each given a weighting of 0.2. In the high economic weighted MCE, the two economic criteria were each given a high weighting of 0.25, adding up to 0.5 overall. In this scenario, emissions reductions were given a relatively low weighting of 0.1 in order to reflect its lower importance. Required policy and long-term sustainability were held constant from the previous MCE at 0.2 each. This allows changes in the outcome of the two MCEs to be attributed to changes in the values of the decision maker.

5.5.3.1 *MCE for High Emissions Reductions Consideration*

Table 19: MCE based on high emissions reduction consideration.

	Proposed Alternatives				
Criteria	Criteria Weighting	Alternative Fuels	Advanced Internal Combustion Engine	Hydrogen Fuel Cells	Electric-Gasoline Hybrids
Best Emissions Reductions	0.4	1.2	1.6	0.4	0.8
Least Required Infrastructure	0.1	0.3	0.2	0.4	0.1
Greatest Public Acceptance	0.1	0.3	0.1	0.4	0.2
Least Required Policy	0.2	0.8	0.2	0.6	0.4
Long-term Sustainability	0.2	0.6	0.8	0.2	0.4
Total		3.2	2.9	2.0	**1.9**

5.5.3.2 *MCE for High Economic Consideration*

Table 20: MCE based on high economic consideration (infrastructure and long-term sustainability).

	Proposed Alternatives				
Criteria	Criteria Weighting	Alternative Fuels	Advanced Internal Combustion Engine	Hydrogen Fuel Cells	Electric-Gasoline Hybrids
Best Emissions Reductions	0.1	0.3	0.4	0.1	0.2
Least Required Infrastructure	0.25	0.75	0.5	1.0	0.25
Greatest Public Acceptance	0.25	0.75	0.25	1.0	0.5
Least Required Policy	0.2	0.8	0.2	0.6	0.4
Long-term Sustainability	0.2	0.6	0.8	0.2	0.4
Total		3.2	2.15	2.9	**1.75**

6. RESULTS, ANALYSIS AND DISCUSSION

6.1 Results of the Multi Criteria Evaluations (MCEs)

Under equal weighted MCE, the ranking of alternatives from the most promising to the least promising are Hybrid Vehicles, Advanced ICEs, Hydrogen Fuel Cells and Alternative Fuels. Under the High Emissions Reductions Consideration MCE, the rankings are Hybrid Vehicles, Hydrogen Fuel Cells, Advanced ICEs and Alternative Fuels. Under the High Economic Consideration MCE, the rankings are Hybrid Vehicles, Hydrogen Fuel Cells, Advance ICEs and Alternative Fuels.

From the above results, Hybrid Vehicles emerge as the most promising alternative under all three of the scenarios. Under the High Emissions Reductions Consideration MCE, the Hydrogen Fuel Cell option scores only slightly less than Hybrids. However, under the High Economic Consideration MCE, The Hydrogen Fuel Cell ranks dramatically lower as an option. This difference is attributable to the fact that Hydrogen Fuel Cells were ranked the lowest in both of the economic cost criteria (Infrastructure and Public Acceptance), coupled with the fact that under the High Economic Consideration MCE, these criteria were weighted the highest. Another interesting result is that the Alternative Fuels option ranked as the least promising option under all three of the scenarios. This is probably due to the initial low rankings it received under every criterion in the equally weighted MCE (See Figure 14).

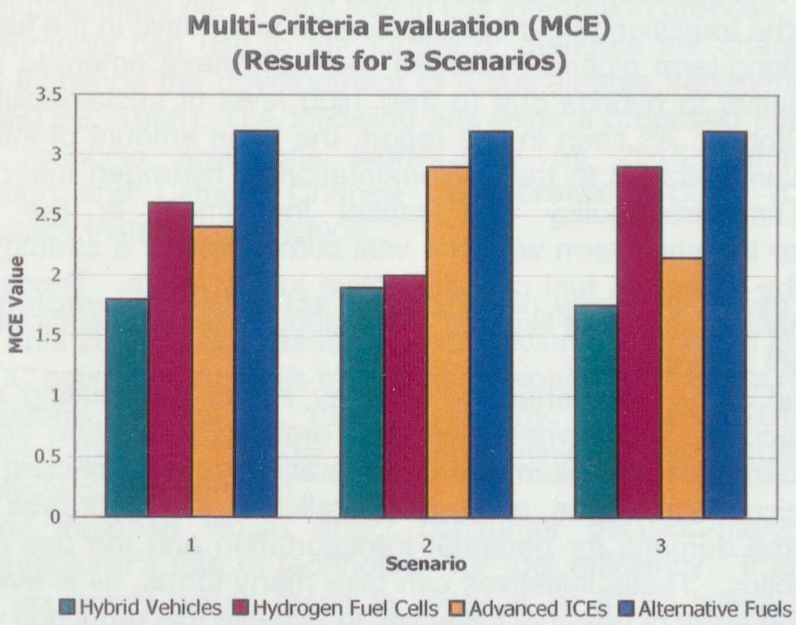


Figure 14: MCE results for the three scenarios (1. equal weighting; 2. high emissions weighting; 3. high economic weighting).

6.2 The Strategy

Limitations to the study were recognized throughout the process of strategy development. They included:

- Access to information and current data
- Time constraints
- Minimal financial resources
- Factors that make it difficult to forecast the future of transportation systems in Canada, for example, the multitude of stakeholders involved and the time required implementing new technologies.
- Existing regional differences across Canada as well as the contrasting needs of urban and rural communities required the development of a general strategy, as opposed to a site-specific one.

Due to the above constraints, STAG was forced to narrow the focus to only some potential alternatives. Preliminary research assisted in the selection of four technological alternatives (alternative fuels, advanced ICEs, hybrids, and hydrogen fuel cells). Based on the goals and information presented in this report, the following Canada-wide strategy to reduce emissions is proposed.

The results of the MCEs have indicated that any strategy for transportation in Canada for 2015 and beyond should include hybrid vehicles as a main component. However, hybrids are not sustainable in the long-term, as they still require a non-renewable resource resulting in harmful emissions. For this reason, hybrid vehicles may be considered as a short-term alternative, being an integral part of the transition to a more sustainable alternative in the future. When looking at the long-term picture hydrogen fuel cells have emerged as a more probable alternative to hybrids due to their high level of sustainability and low environmental impact. As seen in this report, the large amount of infrastructure needed is a main limitation to the implementation of hydrogen fuel cells in the short term. Therefore, policy and capital investment in the necessary infrastructure for the short term will be a vital component of a strategy aimed at implementing the hydrogen fuel cell alternative in the future. These economic and political changes are most likely to come about if there is sufficient demand for hydrogen fuel cell vehicles.

The need for a comprehensive strategy aimed at reducing automobile dependency becomes clear when Canada's growing population and growing transportation demands are taken into consideration (refer to section 5.1). Any new technological alternatives must be paralleled with initiatives aimed at reducing both the demand for personal transportation and the use of privately owned automobiles. These initiatives can take many forms, as is evident in the list below. A wide array of possible initiatives to achieve this reduction will play an essential role in a transportation strategy. Please refer to section 5.4.3 for more in-depth explanations of these initiatives.

Infrastructure-based initiatives:
(1) *Car pooling*
(2) *Van-pooling*
(3) *High occupancy vehicle lanes*
(4) *Public transport improvements*
(5) *Land-use patterns and urban zoning*
(6) *Bicycle and pedestrian programs*

Economic-based initiatives:
(7) *Road pricing*
(8) *Parking management*
(9) *Fuel taxes, license fees, and gas-guzzler taxes*

Employer-based initiatives
(10) *Alternative work hours*
(11) *Tele-commuting*

Public awareness
(12) *Education and promotion*
(13) *Mandatory inspection and maintenance programs*
(14) *Mandatory vehicle scrapage programs* (Robinson, p.1191, 1997)

The need for a comprehensive strategy, which integrates new technology, such as the hydrogen fuel cell, with the implementation of public initiatives aimed at reducing automobile dependency, has been identified. New and revised policies can potentially play a vital role in this integration process. Policies are the tools governments can use to encourage or mandate the changes required to create and influence the development of a sustainable transportation system in Canada (NRTEE, 1996). The following are several proposed policy instruments aimed at reducing emissions significantly by 2015, adopted from the Transportation and Climate Change Collaborative (TCCC) (ORTEE, 1995). Proposed policy instruments include:

a) **Automotive gasoline tax increase**: an annual increase of 2 cents per litre until 2015. A tax based on annual kilometers driven is also an option. TCCC estimated that this tax increase would result in the reduction of CO_2 emissions relative to 1990 levels by the year 2015. Fuel taxes implemented by Canada have had minimal effect due to the strong elasticity of fuel demand.
A tax increase would affect consumer decision-making as well as manufacturer's use of technology for fuel efficiency. It is estimated that this tax policy would result in revenue of $1.53 billion annually in the province of Ontario alone by the year 2015.

b) **Feebates:** applying graduated taxes or rebates to new vehicle purchases depending on whether or not the vehicle is above or below an energy efficiency reference point (such as rated fuel economy). This would have an immediate effect on consumer purchasing decisions. Currently, Ontario's Tax for Fuel Conservation is the only feebate program in North America, however it only affects 1% of the cars on the road. Redesigning the feebate to apply to a broader range of vehicles would provide greater emission reduction potential.

c) **Parking policies**: the majority of automobile commuters enjoy employer subsidized parking and are therefore not paying the full costs of automobile use. Using taxation and regulation to influence parking pricing and supply would encourage a reduction in automobile use. It is estimated that parking policies could affect 16% of vehicle travel in Ontario.

d) **Congestion pricing**: this policy would discourage the use of automobiles during rush hours and peak period use. Due to the fact that it can only affect peak hour travel in the most congested areas, it is unlikely to provide the emission reduction potential of broader based policy instruments.

e) **New Corporate Average Fuel Economy (CAFE) standards**: CAFE standards require automobile manufacturers to meet minimum fuel efficiency standards for all vehicles sold in a model year. It has been more politically accepted than fuel taxes because it placed the responsibility on the manufacturers and not on the consumers. It is not the best policy because it encourages vehicle use due to the reductions in operation cost as a result of improved fuel economy and domestic manufacturers are at a disadvantage to import manufacturers who tend to offer smaller, more fuel efficient, automobiles.

f) **Inspection and maintenance programs**: this would reduce fuel consumption and emissions by improving vehicle maintenance. Programs such as Ontario's DriveClean and B.C.'s AirCare are some successful examples but more of these initiatives with even higher standards need to be put in place.

Public opinion on transportation in Canada was gauged through the use of a survey. Results of the survey were taken into account while ranking the alternatives in the MCE under the specific criteria of public acceptance. This can only be considered as a preliminary survey and a more extensive survey is necessary to assess Canada-wide public opinion.

In order to allow for easy implementation, a more generalized model has been derived from the process of developing this strategy. This framework will allow for development of a more situation-specific strategy for sustainable transportation.

Step 1: Public consultation

Step 2: Implement short-term technology
- Policy tools to facilitate implementation
- Public education

Step 3: Initiation of long-term technology if different from short-term technology
- Policy tools to facilitate implementation
- Public education

Step 4: Commence public initiatives to decrease dependency on the automobile

Selection of specific technologies, policies, and initiatives will depend on the values and goals of decision-makers, as well as varying the weighting of criteria during MCEs. This framework will allow for the tailoring of the strategy to the appropriate scale of implementation, for example, at federal, provincial, regional or municipal levels.

7. CONCLUSION

Throughout the extent of this report, a large variety of information relating to transportation in Canada was presented. The background section described the issues of concern, stating that automotive transportation is a major contributor to fossil fuel emissions and as our population grows, the number of automobiles on the road increases. The current emission levels and transportation policies were summarized and analyzed. Based on this information, STAG was able to project a future transportation scenario and offer alternatives. Canada's current situation was researched, outlining the current demand for alternative fuels, advanced ICEs, hybrids, and hydrogen fuel cells. In order to rank the potential options, criteria were selected and defined. These criteria were:

1. Emissions reductions
2. Cost of infrastructure
3. Public acceptance
4. Required policies
5. Long-term sustainability.

MCEs were used to evaluate each of the technological options and determine which should be included in the final strategy. In addition, it was also necessary to recognize the importance of reducing society's dependence on the automobile. Therefore, economic and political initiatives to reduce emissions and vehicle dependency were also considered. These initiatives are considered integral to any sustainable transportation strategy. Some of these initiatives included: car-pooling, improved community planning, higher gasoline taxes, enhanced public transportation and bicycle systems

The importance of considering public opinion when determining the feasibility of the strategy was not ignored. Public acceptance issues were addressed through the distribution of a survey.

The final strategy was comprehensive and included the implementation of technological alternatives, accompanying policy tools, and initiatives aimed at reducing dependency on the automobile. According to the final analysis, hybrid vehicles emerged as the most promising technological alternative to the status quo in the short-term and hydrogen fuel cells were deemed to be the best long-term alternative.

The final transportation strategy, as presented in this report reflects the aforementioned criteria, constraints, and socio-economic issues. STAG hopes that this strategy will provide a feasible alternative to the current situation in Canada, and that it will successfully result in a significant reduction of vehicle emissions.

8. REFERENCES

Ahrens, C.D. 1994. Meteorology Today: An Introduction to Weather, Climate, and the Environment. New York: West Publishing Company, 5th edition.

Ballard. 2000. Ballard Power Systems Website. <http://www.ballard.com>. Accessed February 9, 2001.

Billings, R.E., and M. Sanchez. 1995. "Solid polymer fuel cells: An alternative to batteries in Electric vehicles – An overview". International Journal of Hydrogen Energy 20:7. pp. 521-529.

Bunting, T., and P. Filion (eds.). 2000. Canadian Cities in Transition: The twenty first century. Toronto: Oxford University Press, 2nd edition.

Burch, S.D., Keyser, M.A., Colucci, C.P., Potter, T.F., and D.K. Benson. 1996. "Applications and Benefits of Catalytic Converterthermal Management". Presented at SAE Fuels and Lubrications meeting. May 7, 1996.

Canadian Automobile Association (CAA). 1999. 1999 Vehicle Durability Survey Results. <http://www.caa.ca/CAAInternet/automobile&consumerservices/vds/vds13.htm>. Accessed January 13, 2001.

Christopherson, R. 1998. Elemental Geosystems. New Jersey: Prentice Hall Inc.

Dale, J.D., Checkel, M.D., and P.R. Sny. 1997. "Application of high energy ignition systems to Engines". Progression in Energy and Combustion Science 23:1. p.379-398.

Diem, W. 2000. "Drivers turn to diesel in Europe". Detroit Free Press. November 30, 2000. <wysiwyg://7/http://www.auto.com/industry/diesel30_20001130.htm>. Accessed March 29, 2000.

Environment Canada. 1995. Technical Supplement to the Environment Indicator Bulletin on Canadian Passenger Transportation, SOE Technical Supplement 95-3. Ottawa: Environment Canada, State of Environment Reporting Program.

Environment Canada. 1997a. Sustainable Transportation. <http://www.ec.gc.ca/agenda21/97/mono2.htm>. Accessed January 31, 2001.

Environment Canada. 1997b. Understanding Atmospheric Change. (A State of the Environment Report No. 95-2). Ottawa: Environment Canada.

Environment Canada. 1997c. Trends in Canada's Greenhouse Gas Emissions (1990-1995). Catalogue No. En49-5/5-8E, Ottawa: Environment Canada.

Environment Canada. 1998. Climate Change, SOE Bulletin No. 98-3. Ottawa: Environment Canada, State of Environment Reporting Program.

Environment Canada – EcoAction 2000. 2000a. Canada Transportation Challenge: Down to Earth Choices on the Drive Toward a Healthy Environment. Hull, Quebec: Environment Canada.

Environment Canada. 2000b. Government of Canada Actions on Clean Air. <http://www.ec.gc.ca>. Accessed January 31, 2001.

Environment Canada. 2000c. Criteria Air Contaminant Emission (CAPE) Summaries. <http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm>. Accessed March 12, 2001.

Environment Canada. 2001. Acid Rain FAQ. <http://ns.ec.gc.ca/aeb/ssd/acid/acidfaq.html>. Accessed March 6, 2001.

Europa. 2000. Europa Website. <http://www.europa.eu.int>. Accessed March 10, 2001.

Ford, T. 1999. "Fuel Cell vehicles offer clean and sustainable mobility for the future". Oil and Gas Journal. Dec 13, 1999.

Gordon, D. 1995. Transportation and energy: Sustainable transportation and how we get there. Washington, D.C.: American council for an Energy-Efficient Economy.

Government of British Columbia. 2000a. British Columbia Evaluates Post-2004 Motor Vehicle Emission Standards. <http://www.env.gov.bc.ca/main/newsrel/fisc9900/march/bg190a.htm>. Accessed February 11, 2001.

Government of British Columbia. 2000b. AirCare program homepage. <http://www.aircare.ca>. Accessed March 11, 2001.

Government of Canada. 2000a. Alternative Fuels Act. Ministry of Justice. <http://canada.justice.gc.ca/en/laws/A-10.7/text.html>. Accessed February 15, 2001.

Government of Canada. 2000b. Report on the Application of the Alternative Fuels Act Fiscal Year 1999 – 2000. Treasury Board of Canada Secretariat. <http://www.tbs-sct.gc.ca/report/other/afa00_1_e.html>. Accessed February 11, 2001.

Government of Ontario. 2000. DriveClean program homepage. <http://www.driveclean.com>. Accessed March 11, 2001.

Gushee, D.E. 1992. "Alternative fuels for cars: Are they cleaner than gasoline?" Chemtech 22:7. pp. 406-411.

Heanne, K., and S.B. Petty. 1998. Sustainable transportation: The road from Kyoto. Public Roads. March/April.

Hermance, D. and S. Sasaki. 1998. Hybrid electric vehicles take to the streets. IEEE Spectrum, Special Report. pp. 48 – 52.

Honda Canada. 2000. Honda Canada Website. <http://www.honda.ca>. Accessed December 10, 2000.

HybridCars. 2000. HybridCars Website. <http://www.hybridcars.com>. Accessed January 6, 2001.

International Institute for Sustainable Development (IISD). 2001. Government Budgets and Case Studies. http://iisd1.iisd.ca/greenbud/taxfuel.htm. Accessed January 22, 2001.

Japan Automobile Manufacturers Association of Canada. 1998. Japan Automobile Manufacturers Association of Canada Website – Hybrid Vehicles. <http://www.jama.ca>. Accessed February 2, 2001.

Jay, M. 1998. "Strategic plans and sustainable transportation". Planning Quarterly. March 1998: 20-23.

MacLean, H.L., and L.B. Lave. 2000. "Environmental Implications of Alternative Fueled Automotives: Air quality and greenhouse gas trade offs". Environmental Science And Technology 34:2. pp. 225-235.

Moran, J.M., and M.D. Morgan. 1994. Meteorology: The Atmosphere and the Science of Weather. New York: MacMillan College Publishing Co., 4th edition.

National Round Table of the Environment and the Economy (NRTEE). 1996. Sustainable Transportation in Canada: Backgrounder. Ottawa: NRTEE.

National Round Table on the Environment and the Economy (NRTEE). 1997. The road to sustainable transportation in Canada. Ottawa: NRTEE.

Natural Resources Canada. 1997. Energy-related research and development by federal and provincial governments 1983 – 1997. Ottawa: Office of Energy Research and Development.

Natural Resources Canada. 2000. The Auto$mart Program Homepage. <http://autosmart.nrcan.gc.ca/home_E.htm>. Accessed February 11,2001.

Ontario Round Table on Environment and Economy (ORTEE). 1995. History of the Ontario Round Table on Environment and Economy. <http://www.web.net/ortee/main.html>. Accessed February 16, 2001.

Ontario Round Table on Environment and Economy (ORTEE). 1996. The Role of Transportation Technology in Reducing Greenhouse Emissions. <http://www.web.net/ortee/transportation/report3/summary.html>. Accessed February 13, 2001.

Ontario Transportation and Climate Change Collaborative (OTCCC). 1995. Report 9: A policy instruments working paper on reducing carbon dioxide emissions from the transportation sector in Ontario. <http://www.web.net/users/ortee/transportation/report9/exsum.html>. Accessed February 16, 2001.

Organization for Economic Co-operation and Development (OECD). 1997. Road Transport Research Outlook 2000. Paris: OECD.

Pacific Northwest Pollution Prevention Resources Centre (PNPPRC). 1999. Topical Reports: Alternative Fuel for Fleet Vehicles. <http://www.pprc.org/pprc/pubs/topics/altfuels.html>. Accessed January 20, 2001.

Pembina Institute for Appropriate Development, The. 2000. "Climate Friendly Hydrogen Fuel: A comparison of the lifecycle of greenhouse gas emissions for selected fuel cell vehicles and hydrogen production systems". The Pembina Institute for Appropriate Development Webpage. <http://www.pembina.org>. Accessed January 13, 2001.

Robinson, R. 1997. "Transportation demand management in Canada: an overview". Energy Policy, 25:1. pp. 1189-1191.

Roseland, M. 1998. Towards Sustainable Communities. Gabriola Island, BC: New Society Publishers.

Sierra Club. 2000. Sierra Club of Canada Climate Change Project. <http://www.sierraclub.ca/national/climate/emm.html>. Accessed January 12, 2001.

Sperling, D. 1995. Future Drive: Electric Vehicles and Sustainable Transportation. California, USA: Island Press.

Statistics Canada. 1995. Government pollution abatement and control expenditures. <http://www.statcan.ca/english/Pgdb/Land/Environment/envir07e/htm>. Accessed January 8, 2001.

Stewart, G., and R. Pringle. 1997. "Toronto's tentative approach to TDM". Energy Policy 25:1. pp. 1203-1212.

Thomas, C.E., Kuhn, I.F., James, B.D., Lomax, F.D., and Baum, G.N. 1998. "Affordable hydrogen Supply pathways for fuel cell vehicles". International Journal of Hydrogen Energy 23:6. pp. 507-516.

Toyota Canada. 2000. Toyota Canada Website. <http://www.toyota.ca>. Accessed December 10, 2000.

Transport Canada. 1996. Canadian Transportation Act. <http://www.tc.gc.ca/actregs/special/tcacts-e.html>. Accessed January 8, 2001.

Transport Canada. 1999. Transportation and Climate Change: Options Paper for the Transportation Climate Change Table, November 1999. <http://www.tc.gc.ca/envaffairs/ subgroups1/Options_Paper/English/>. Accessed January 13, 2001.

Transport Canada. 2000. Transportation in Canada 1999 Annual Report. Transport Canada, TP 13198E, 2000.

Union of Concerned Scientists (UCS). 2000. Cars and Trucks and Air Pollution. <http://www.ucsusa.org/vehicles/cars.html>. Accessed March 6, 2001.

United States Department of Energy. 2000. U.S. Department of Energy Homepage. <http://www.eren.doe.gov>. Accessed March 10, 2001.

United States Environmental Protection Agency (EPA). 2001a. Global Warming: Climate. <http://www.epa.gov/globalwarming/climate/index.html>. Accessed March 6, 2001.

United States Environmental Protection Agency (EPA). 2001b. Environmental Issues: Acid Rain. <http://www.epa.gov/airmarkest/acidrain/>. Accessed March 6, 2001.

United States Environmental Protection Agency (EPA). 2001c. Global Warming: Answers to Frequently Asked Questions. <http://www.epa.gov/globalwarming/faq/index.html>. Accessed March 6, 2001.

APPENDICES

APPENDIX 1

Transportation Survey

In less than 100 years, we've gone from horse and buggy to 14 million cars on Canada's roads. Along the way, the car has become a way of life and an integral part of the economy. In such a short time the car has changed the way we do business, get to work, plan our cities, organize our family schedules and even the way we conduct our courtships!

And, in less than 100 years, the car has come to have a major impact on our environment and our health.

Our group of Environmental Science students has put together this survey from an Environment Canada publication and we would like to determine the community's response to the transportation challenges that our society faces today.

If you could fill out this survey and return it to us, your thoughts and potential lifestyle changes will become a part of a transportation strategy that we are developing as part of a final group project for our degrees in Environmental Sciences.

All responses, names and addresses will be kept confidential.

Sincerely,

The Sustainable Transportation Advisory Group

Jill Lamberts	Lindsay Snow
Robert Vitale	Mike Gunsinger
Marney Isaac	Karen Sutherland
Ione Smith	Angela Vandersluis

What choices will you make? We want to hear from you!

[1] What is your main form of transportation? (choose one)

- ❑ car
- ❑ bicycle
- ❑ ride-sharing
- ❑ public transit
- ❑ walking

Please circle your answer for the following question:
1 = definitely willing; 2 = somewhat willing; 3 = not at all willing;
4 = not possible; 5 = already doing it as much as possible

---

[2] How willing would you be to take each of the following actions to reduce vehicle air pollution in your area?

a. Use public transit twice a week more than you do now
1 2 3 4 5

b. Walk or cycle instead of driving for two or more of your shorter trips each week
1 2 3 4 5

c. Share a ride with others twice a week more than you do now
1 2 3 4 5

d. Keep car better tuned and purchase most efficient vehicle possible to meet your needs
1 2 3 4 5

e. Make walking, biking or using public transit a part of your trip to work
1 2 3 4 5

f. Chain your trips (2 or more together) to the grocery store, recreational facilities and other public or retail services
1 2 3 4 5

[3] Approximately how many kilometres do you drive each week? __________
How many kilometres could be saved, realistically, by undertaking some of the measures above? __________

[4] What keeps you from reducing your car use further?

____

____

[5] What are the two most important reasons that would prompt you to reduce your car use?

____

____

[6] The transportation system has many different external costs. Which are of most concern to you?

- ❑ road construction/maintenance
- ❑ inefficient land use/foregone land use
- ❑ space use for parking
- ❑ non-renewable fuel consumption
- ❑ disruption of existing communities
- ❑ health
- ❑ noise pollution
- ❑ air pollution
- ❑ climate change
- ❑ accidents

[7] If you had the power to make decisions for the country and you wanted to reduce the cost of the transportation system, which of the following options would you pursue? (check all that apply)

- ❑ provide incentives for car owners to reduce use
- ❑ increase the price of gasoline dramatically
- ❑ offer insurance breaks to drivers who car pool
- ❑ increase price of city center parking
- ❑ require vehicle owners to have their cars and trucks pass an annual vehicle and emission inspection, with a penalty for those who fail to meet standards
- ❑ start a gas-guzzler tax – an extra tax paid by purchasers of less fuel-efficient new vehicles
- ❑ start road pricing – an extra charge paid to allow drivers to travel in certain areas during rush hour
- ❑ introduce exclusive lanes for cycling, buses and better facilities for pedestrians
- ❑ zoning changes to favour mixed use

[8] What changes to your public transit system would prompt you to use it more?

____

____

[9] If you could change three things about your community to allow you to use your car less often, what would they be?

1. ______________________________
2. ______________________________
3. ______________________________

[10] Any other comments….

____
____
____
____

What is your driving profile?

1. How many cars does your household own?

❑ 0 ❑ 1 ❑ 2 ❑ 3

2. How often do you use your car with only yourself and no passengers?

❑ all the time ❑ most of the time

❑ not very often ❑ none of the time

3. List the three places you usually visit most during the week, the distance from your home and how you get there (walk, bike, bus, train, carpool, car, etc.)

Where?	Distance	Method of Transportation
a. ________	______ km	______________
b. ________	______ km	______________
c. ________	______ km	______________

Of those you drive to, which locations could you have conveniently biked, walked, taken transit or shared a ride to?

____
____

source: Environment Canada – EcoAction 2000
"Canada's Transportation Challenge"

Thanks for your time and consideration!
The Sustainable Transportation Advisory Group

APPENDIX 2

Acronyms

CAA	Canadian Automobile Association
CAC	Criteria Air Contaminants
CAD	Canadian Funds (dollars)
CAFÉ	Corporate Average Fuel Economy Standards
CEPA	Canadian Environmental Protection Act
CH_4	Methane
CIDI	Compression Ignition Direct Injection
CO_2	Carbon Dioxide Gas
CO	Carbon Monoxide
E85	Ethanol Fuel with 85% ethanol and 15% gasoline
E100	Ethanol Fuel with 100% ethanol
EPA	United States Environmental Protection Agency
FCVs	Fuel Cell Vehicles
GHGs	Greenhouse Gases
HCs	Hydrocarbons
HOV	High Occupancy Vehicle lanes
ICEs	Internal Combustion Engines
IISD	International Institute for Sustainable Development
IJC	International Joint Comission
IMA	Integrator Motor Assist power train
IPCC	Intergovernmental Panel on Climate Change
M85	Methanol Fuel with 85% methanol and 15% gasoline

M100	Methanol Fuel with 100% methanol
MCE	Multi-Criteria Evaluation
MOU	Memorandum of Understanding
NAPCC	National Action Program on Climate Change
NLEV	National Low Emission Vehicles
NOx	Nitrogen Dioxides
NTREE	National Round Table of the Environment and the Economy
O_3	Ozone Gas
OECE	Organization for Economic Co-operation and Development
ORTEE	Ontario Round Table on Environment and Economy
PART	Total Particulate Matter
PM	Particulate Matter
PM10	Particulate Matter (10 μm)
PM2.5	Particulate Matter (2.5 μm)
PNGV	Partnership for a New Generation of Vehicles
PNPPRC	Pacific Northwest Pollution Prevention Resources Centre
ppm	Concentration in Parts Per Million (mg/L of a gas)
RPMs	Revolutions per Minute
SIDI	Spark Ignition Direct Injection
SO_2	Sulphur Dioxide
STAG	Sustainable Transportation Advisory Group
SULEV	Super Ultra Low Emission Vehicle
TCCC	Transportation and Climate Change Collaborative
UCS	Union of Concerned Scientists
ULEV	Ultra Low Emission Vehicle

VCR	Voluntary Challenge and Registry
VOCs	Volatile Organic Compounds