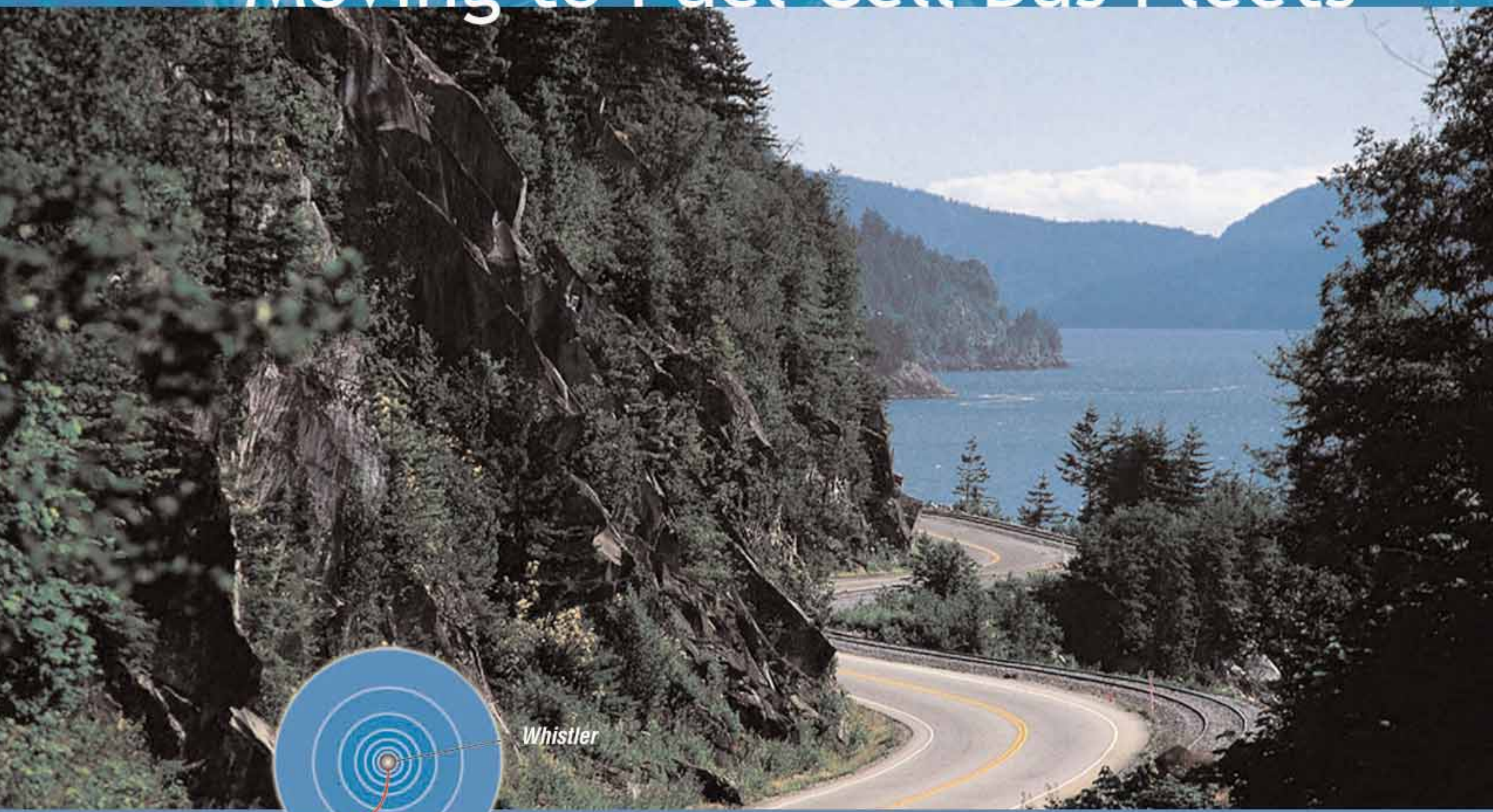
# PATH TO PURCHASE:
## Moving to Fuel Cell Bus Fleets




*Hydrogen Highway™*
*British Columbia, Canada*

**BC Transit's Project Vision:**
*To accelerate fuel cell bus commercialization by deploying a fleet of 20 hydrogen fuel cell buses in regular revenue service thereby advancing Canada's leadership in establishing a hydrogen economy.*

BC Transit

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# Executive Summary

### BACKGROUND

In the year 2000, Canada, as part of a world community concerned about the environmental, social and economic consequences of increasing greenhouse gas emissions, announced its Action Plan 2000 on Climate Change.

The Government of Canada committed to work with industry and other levels of government to develop and demonstrate hydrogen-based technologies that would enable Canada to reduce greenhouse gas (GHG) emissions while enhancing its innovative economy. As part of this commitment, the Federal Government launched the Canadian Transportation Fuel Cell Alliance (CTFCA) to support the demonstration and evaluation of different methods of hydrogen production and delivery to fuel cell vehicles. Canada is not alone in this effort. Throughout the world, governments and industry have combined to create a momentum that makes commercial introduction of hydrogen fuel cell vehicles an inevitability.

Adoption of this technology by public transit systems is particularly compelling. Seen as an efficient mover of people, public transit fleets – now powered principally by diesel – are a natural platform for the introduction of a power technology that is environmentally benign.

The development of the fuel cell drive system in bus applications has been led by Canada. Of the 100 fuel cell buses that have been produced globally for demonstration, power systems for at least 60 of them have been supplied by Canadian companies.

While these projects have been valuable in assessing technical performance, each demonstration has been restricted to small numbers of buses (one to three) in any one location. The next logical step, confirmed as a recommendation from a recent CTFCA study, is to move to a fuel cell bus fleet demonstration that will place sustained, long term demand on operations, maintenance and fueling activities of an urban transit system (UTS).

BC Transit is a Crown Corporation of the Government of British Columbia with a track record of successfully identifying, adopting and operating new vehicles and fuel systems in revenue service. Seeing the need and opportunity to advance the commercialization of hydrogen fuel cells in transit applications, BC Transit has offered to purchase a fleet of 20 hydrogen fuel cell hybrid buses. These would operate in regular revenue service in the Resort Municipality of Whistler before, during and after the Vancouver 2010 Olympic and Paralympic Winter Games (2010 Games).

The purpose of this purchase would be to evaluate the integration of a hydrogen fuel cell bus fleet this large into the daily operations of a transit system over the life cycle for a conventional bus – 20 years. A commercial purchase of this number of fuel cell buses is unprecedented.

### THE STUDY

Before engaging in such an ambitious project, BC Transit, with support from the CTFCA, studied the rationale and feasibility of such a purchase and prepared a plan to guide implementation and management of the purchase and deployment of the fleet.

The study was to determine:

1. if the bus manufacture, fuel cell system and fuel supply industries are ready and able to supply the fleet and fueling infrastructure in the timeframe and to the specifications required
2. the financing premium required over and above the costs of 20 conventional diesel electric hybrid buses and
3. the social benefits and economic opportunities this purchase held for Canada and British Columbia into the future.

## Rationale

Many circumstances converge to justify this particular purchase by BC Transit for operation in Whistler at this time. Chief among them is the global commitment to reduce greenhouse gases in an effort to mitigate the effects of climate change, to make cities, in particular, more livable and to reduce the personal, social and economic costs of health damage caused by GHGs. As part of that commitment, Canada ratified the Kyoto Protocol in December, 2002 and has set as its target to reduce GHG emissions to 6% below 1990 levels between 2008 and 2012.

Canadian innovation in fuel cell research and development, based principally in British Columbia, is recognized worldwide and Canadian firms are well positioned to capitalize on the market opportunities that full scale commercialization of this technology will bring. Hybridization of fuel cell drive systems will increase efficiency and lower cost, accelerating commercialization of transit applications. There is, however, major competition on the world stage.

The Resort Municipality of Whistler is actively working to sustain airshed quality to preserve its international reputation as a pristine natural destination.

BC Transit, as the purchaser, owner and operator in Whistler of a fuel cell fleet, has the will, the skill and the commitment to ensure success.

The 2010 Games, billed as "Sustainable Games", present a singular opportunity to showcase a location, a technology and a jurisdiction that offer environmental solutions and innovative opportunities to the world.

Canada and British Columbia have renewable sources of energy from which hydrogen can be made, offering a transportation solution that is truly zero emission.

The focus of British Columbia's Hydrogen and Fuel Cell Strategy is the formation of the Hydrogen Highway™, launched by Prime Minister Paul Martin at Globe 2004 in Vancouver. The purchase and operation of 20 hydrogen fuel cell- powered buses would serve as the centrepiece of this initiative.

## Methodology

With this rationale to endorse its vision, BC Transit formed a study team to examine current fuel cell bus activity around the world, transit bus market potential, environmental and health benefits, logistics, risks and financing. In June, 2005 it convened a gathering of some 70 leaders in the bus, hydrogen, fueling and fuel cell industries to seek their input as to the viability, risks and costs of the proposed purchase. Nine responses were received from industry as a result of the Request for Information that was distributed at that meeting. Five responses addressed bus proposals and four addressed fuel supply and fueling infrastructure.

## Conclusions

The overriding conclusion from this study is that the proposed purchase by BC Transit of 20 hydrogen fuel cell hybrid buses is not only feasible but ideally timed to:

- maximize public policy goals of GHG reduction contributing to Canada's Kyoto targets
- participate in the Hydrogen Highway™; the focal point of British Columbia's Hydrogen and Fuel Cell Strategy
- advance Canada's industrial lead in this sector
- contribute to the sustainability goals of the 2010 Games and
- capture the world's attention during those Games as an innovative jurisdiction

The fuel cell bus delivers GHG benefits 3.67 times greater than the diesel electric hybrid alternative. With 7,000 transit buses scheduled for replacement in Canada between 2015 and 2025, replacement of diesel powered fleets with hydrogen fuel cell fleets could result in GHG savings of some 19 million tonnes over the life of those buses.

Health care costs attributable to air pollution in British Columbia is estimated at $167 million a year. A large part of that is the result of fossil fuel combustion.

This purchase, by its unprecedented nature, will accelerate the commercialization of hydrogen fuel cells for heavy duty applications and strengthen the abilities and prospects of Canadian players in this sector to move more quickly from cost to profit. It will also facilitate the commercial development of hydrogen infrastructure.

Globally, governments are recognizing the benefits of hydrogen and fuel cell technologies. Canada, having led global advances in fuel cell systems and bus platforms, faces the prospect of losing commercialization benefits to other jurisdictions unless a substantial fleet of fuel cell buses is deployed soon to stimulate the domestic industry.

The cost of this fleet and its operation is estimated to total $89 million – triple the cost of a fleet of 20 buses powered by incumbent technology. BC Transit has committed to investing $31.4 million –equivalent to the cost of purchasing and operation of 20 diesel electric hybrid buses. The shortfall of $57.6 million is being sought from governments whose public policy objectives would be served by this project.

To ensure timely manufacture, delivery and deployment, funding commitments need to be made by March, 2006 so that purchase orders can be issued by June, 2006. If these commitments cannot be met, the purchase cannot proceed in time to maximize use and exposure at the 2010 Games.

## Recommendation

Having studied this opportunity and determined that the purchase of a fleet of 20 hydrogen fuel cell buses is feasible within the timeframe and to the required specifications, the overarching recommendation is that governments – to satisfy their environmental, social and economic policy goals and to advance Canada's leadership in commercializing zero emission transportation technology – work collaboratively to provide, by March 31, 2006, up to $60 million over five years in support of deployment.

*"So we have a choice – we can be passive spectators, each watching the show as it unfolds around us or we can be champions, seizing the opportunity to shape the future into the reality we would like it to be."*

**Jeremy Bentham,** CEO, Shell Hydrogen,
November, 2003

™ Hydrogen Highway is a trade-mark of Fuel Cells Canada

# Path to Purchase:

## Moving to Fuel Cell Bus Fleets

### Introduction

The vision of vehicles powered by a zero emission power source has moved from conceptual curiosity to technical reality in less than 25 years. Hydrogen fuel cell vehicles are proving their value in demonstration projects around the world.

Government leadership, industry innovation and business investment have combined worldwide to create a momentum that makes commercial introduction of hydrogen fuel cell vehicles an inevitability.

Adoption of this technology by public transit systems is particularly compelling. Seen as an efficient mover of people, public transit is a natural platform for the introduction of a power technology that is environmentally benign. Members of the Canadian Transportation Fuel Cell Alliance (CTFCA) – a program of Natural Resources Canada – along with agencies around the world have identified public transit systems as attractive early adopters of hydrogen and fuel cell technology.

Canada has been in the vanguard of developing, refining and commercializing hydrogen fuel cell power, particularly in mobile applications. BC Transit, in concert with the governments of Canada and British Columbia and the cluster of hydrogen fuel cell companies, primarily based in British Columbia, has been visionary in its adoption of alternate energy sources, technologies and vehicles.

British Columbia, perceived internationally for its commitment to environmental stewardship, is eager to enhance its reputation by supporting innovation in power technologies and to showcase its commitment during the Vancouver 2010 Olympic and Paralympic Games (2010 Games).

Over the course of the last 20 years a variety of projects has field tested emerging generations of fuel cell power and drive systems in transit buses. While these projects have been valuable in assessing technical performance, they have been restricted to small numbers of buses (one to three) in any one location.

The next logical step is a project of larger size that will place sustained, long term demand on operations, maintenance and fueling activities of an urban transit system (UTS). This is one of the key recommendations of a recently completed CTFCA study that details the timing and requirements for Canadian urban transit systems to move to fuel cell bus fleets.[1]

Building on the vision shared by so many, BC Transit has offered to purchase a fleet of 20 hydrogen fuel cell buses to operate in regular revenue service in the Resort Municipality of Whistler before, during and after the 2010 Games. The focus of this unprecedented purchase would be to evaluate the integration of this fleet into the daily operations and logistics of a transit system over the life cycle of conventional buses.

This report contains results of a study into the feasibility of such a purchase† and a plan‡ that will guide implementation and management of this purchase.

† Methodology can be found in Annex B

‡Implementation Plan and schedule can be found in Annex A

# Chapter 1:

## Path to Here and Now: Fuel Cell Bus Development

*"The commercialization of fuel cells has moved from the improbable 15 years ago, to the possible several years ago, to the inevitable today. … a viable and sustainable hydrogen economy is now a reality and the momentum that is building provides British Columbia with an unparalleled global opportunity to lead this energy revolution"*
**Firoz Rasul**, Chair, Ballard Power Systems
February, 2004

### World Experience to Date

While a number of suppliers internationally have provided bus platforms to carry fuel cell drive technologies, the development of the fuel cell drive system itself in bus applications has been led by Canada. A steadily growing number of fuel cell buses are now in daily use, in different climates, using different technology combinations and fuel storage techniques. The one common factor between these different buses is the success with which they are being operated. [2]

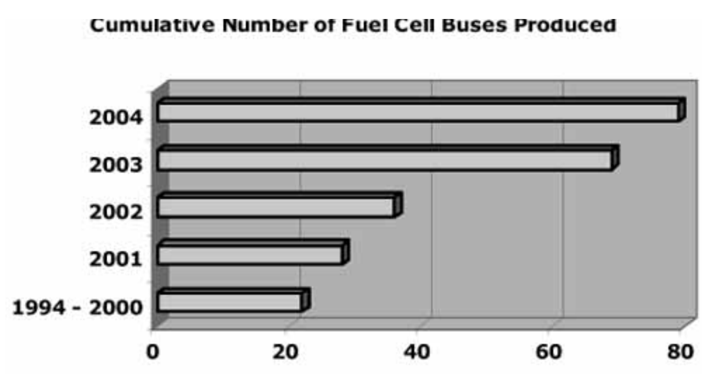



**Fig. 1.1.** Cumulative Number of Fuel Cell Buses Produced Worldwide [2]

Around 100 fuel cell buses have been produced globally, with power systems for at least 60 of them supplied from Canada. Ballard Power Systems of Vancouver, British Columbia, accounts for at least fifty-seven bus engine orders. Completed demonstrations include Georgetown University, the Vancouver and Chicago P3 trials, the Xcellsis ZeBUS P4 program, the NEBUS platform and the MAN bus (10 engines). Current demonstrations include the CUTE, ECTOS and STEP§ programs for the European Union (EU), Iceland and Australia (33 engines). In addition, demonstration orders are now being delivered for California (3 engines) and the UNDP/GEF program for China (3 engines). An order for eight engines is currently under development for Brazil through the UNDP/GEF.**

Hydrogenics of Mississauga, Ontario has supplied bus engines for projects supported by Canada, NorthRhine Westphalia in Germany, and the United States Air Force at Hickam Air Force Base in Hawaii.

§ Clean Urban Transport for Europe (CUTE); Ecological City Transport System (ECTOS) Iceland; Sustainable Transport Energy for Perth (STEP) Australia

**United Nations Development Program/Global Environment Facility (UNDP/GEF)

Government funding support in Canada, particularly to early demonstration programs as well as research and development, has been critical in advancing and validating fuel cell technology for bus applications in preparation for commercial production.

For example, the Province of British Columbia has collaborated with Ballard Power Systems in the serial development of bus engines from P1 to P5 configuration. The P5 engine platform accounts for 39 buses now under test or on order around the world.

At present, Canadian technology is being deployed largely outside Canada in bus demonstration projects funded by competing governments, e.g. CUTE / ECTOS in Europe, STEP in Australia, in the U.S.A. and in China and Brazil through UNDP/GEF. Canada, having led advances in fuel cell drive systems, balance of plant and bus platforms now faces the prospect of losing commercialization benefits to other jurisdictions.

On the basis of significant fuel cell development work in Canada [much of it funded in partnership with Canadian governments] hydrogen fuel cell buses, and thus the beginnings of the hydrogen economy, are now an everyday reality to the citizens of Europe.

### Next Generation Hybridization

Although the CUTE program has demonstrated the functionality and operational reliability of fuel cell buses, the next generation of buses will be fuel cell hybrids. Fuel cell stack manufacturers and system integrators such as Hydrogenics, UTC, ISE and Toyota now offer fuel cell drive systems for buses only in hybrid configurations. DaimlerChrysler, Ballard and NUCellSys have all indicated that their future offerings of fuel cells for buses will be hybrid systems.

Hybridization provides a number of advantages for developers including: increased efficiency with advanced energy storage devices and brake energy recovery, the use of light-duty vehicle rated fuel cell systems, reduced hydrogen consumption and system redundancy.

Hybridization requires the development and construction of an application-specific bus chassis. Retrofits of existing pure fuel cell drive buses are not practicable or cost effective for developers. Development costs for a bus chassis, electric drive components; fuel storage, energy storage and energy recovery systems means initial next-generation bus costs will not differ substantially from today’s fuel cell buses – triple the cost of a conventional diesel bus.

The move to hybridize fuel cell powered light-duty vehicles has value for heavy duty vehicle use. The momentum to hybridize in this light duty market, when allied to the market potential and centralized fueling features of transit applications, can help accelerate the economies of scale necessary for commercialization of all mobile applications.

## Status of Global Activity

A variety of multilateral and national programs for hydrogen fuel cell bus demonstration are at work in many parts of the world.

### UNDP/GEF

The Global Environment Facility (GEF) is a financial mechanism structured as a trust fund that operates in collaboration and partnership with three implementing agencies and is dedicated to achieving global environmental benefits. The United Nations Development Program (UNDP), the development arm of the United Nations, was designated by GEF as one of its three Implementing Agencies.

One of the main aims of the UNDP/GEF program is to accelerate technology transfer to host countries. UNDP provides support to countries in the development of effective policies and institutions, such as integrating environmental and development objectives into national development agendas and processes, to protect the environment as well as reduce poverty.

Specifically, the UNDP/GEF supports projects in the environmental focal areas of biodiversity, climate change, international waters and ozone depletion. The GEF's justification for participating in the Fuel Cell Bus Programme (FCB) was the reduced GHG emissions that FCBs offer over conventional diesel buses. Fuel cells powered by hydrogen can offer dramatic reductions in system-wide GHG emissions from the urban transport sector if the system is carefully designed. To advance the commercialization of Fuel Cell Bus technology for urban areas of developing countries, the UNDP/GEF Fuel Cell Bus Programme proposed a commitment of US $59.6 million with approximately US $36 million approved to date by the GEF Council.

FCB demonstrations and associated refueling infrastructure were planned for the largest bus markets in the developing world; Beijing, Cairo, Mexico City, New Delhi, Sao Paulo and Shanghai. Major progress has been made by GEF in Brazil and China but the projects in Mexico, Egypt and India have been cancelled due to budget constraints of those countries' national governments. This makes the information from non-GEF projects even more relevant to their programme objectives.

Developmental objectives for the GEF FCB programme were based in three phases of support: preparatory, demonstration and commercialization. Beyond the current funding for demonstrations, GEF support for the commercialization phase is contingent on a number of factors, a principal one being "continued investment and interest in the technology within donor countries". GEF intends to make a decision on Phase 3 funding within the next three to eight years. This latest report from UNDP/GEF reinforces the conclusion that the current level of engagement between market players is insufficient to provide a commercialization pathway for fuel cell buses.

## CUTE

The Clean Urban Transport for Europe (CUTE) initiative began with funding approval in 2001 and has seen nine European countries adopt three fuel cell buses each for demonstration in daily service.

| | No. of Buses | Engine Configuration | Power Output (Stack Developer) | Bus Type | Onboard Fuel | Fuel Storage | Fuel Production |
|---|---|---|---|---|---|---|---|
| **CUTE** (2001 – 2005/6) | | | | | | | |
| Amsterdam, Hamburg, Stockholm | 3 | Direct | 250 kW (Ballard) | Citaro (EvoBus) | $CH_2$ | Gas Cylinders | Onsite electrolysis[1] |
| Barcelona | 3 | Direct | 250 kW (Ballard) | Citaro (EvoBus) | $CH_2$ | Gas Cylinders | Onsite *solar* electrolysis |
| London, Luxembourg, Porto | 3 | Direct | 250 kW (Ballard) | Citaro (EvoBus) | $CH_2$ | Gas Cylinders | Centralised off site production[2] |
| Madrid, Stuttgart | 3 | Direct | 250 kW (Ballard) | Citaro (EvoBus) | $CH_2$ | Gas Cylinders | Onsite SMR natural gas |
| **ECTOS** (2001 – 2005) | | | | | | | |
| Reykjavik | 3 | Direct | 250 kW (Ballard) | Citaro (EvoBus) | $CH_2$ | Gas Cylinders | Onsite electrolysis[1] |
| **CityCell** (2003 – 2005) | | | | | | | |
| Madrid, *Turin*[5] | 1 | Hybrid with battery storage | 62 kW (UTC) | Cristalis (Irsibus) | $CH_2$ | Gas Cylinders | Onsite SMR natural gas[3] |
| *Paris*[5] | *1* | *Hybrid with battery storage* | *75 kW (Axane)* | *Cristalis (Irsibus)* | *$CH_2$* | *Gas Cylinders* | |
| **Fuel Cell Bus** (1999 – 2002?) | | | | | | | |
| Berlin, Copenhagen, Lisbon | 1 [4] | Hybrid with battery storage | 75 kW | NL A21 (MAN) | $LH_2$ | Cryo-cylinders | |

1 – the electricity for electrolysis has been certified as "green",
2 – for the centralised production the hydrogen is tanked in, with London being the only city to tank in and store liquid hydrogen,
3 – the refuelling station in Madrid is being used by both the CityCell and CUTE project
4 – the Fuel Cell Bus project had one bus in total, unlike CUTE which has 3 per city,
5 – here italics represent planned buses that have not been delivered.

**Table 1.1** European Union Funded Fuel Cell Bus Trials [2]

With respect to fuel cell buses in the EU, the CUTE program received approximately 18.55 million€ (Cdn $26.2 million), with the total budget for the project estimated at 52.44 million€ (Cdn $74.1 million). When support to ECTOS is added, the total FCB funding rises to 60 million€ (Cdn $84.8 million) with European Union support totaling 21 million€ (Cdn $29.7 million).[3]

Through the CUTE demonstration program the fuel cell engine has proven its functionality and availability under commercial transit use. However, increased fuel cell durability and balance of plant maturity are required. There is at present a systems trade-off between energy efficiency and engine reliability in pure fuel cell drive configurations. CUTE will be completed in December, 2005. It will be followed by a hydrogen fleet project known as HyFLEET:CUTE.

This project will comprise the continued operation of the fuel cell bus fleet from the former CUTE project, the development and demonstration of a new fuel cell hybrid pre-prototype bus and the development, construction and demonstration of a fleet of 14 hydrogen powered internal combustion engine (ICE) buses in regular service in Berlin including the required hydrogen infrastructure. The project is part of the European Hydrogen & Fuel Cell platform. Goals of this project relevant to fuel cell buses are to:

- improve fuel cell technology by continuing the operation of 21 fuel cell buses over a period of 12 months in seven European cities and in parallel continuing the operation in two non-European cities (Beijing and Perth)

- develop the concept, design and production of a new FC hybrid bus as a pre-prototype aiming at 20% less fuel consumption than a comparable diesel bus

European Commission funding in support of HyFLEET:CUTE is currently under negotiation; funding support of at least 19 million € (Cdn $ 26.9 million) is anticipated.

### Fuel Cell Bus Club

The Fuel Cell Bus Club brings together the CUTE (Clean Urban Transport for Europe), ECTOS (Ecological City Transport System) and STEP (Sustainable Transport Energy Project) projects underway in Europe and Australia in the largest fuel cell bus demonstration in the world. Participating as select members are China and BC Transit.

Currently the Fuel Cell Bus Club operates 33 Daimler Chrysler fuel cell buses with Ballard fuel cell systems in ten major European cities and Perth, Australia. Three additional buses are being delivered to Beijing by the end of 2005.

Ballard Power Systems reports that CUTE carries more than 10,000 passengers daily by fuel cell bus, that the equivalent of 56 bus years of operational experience has been achieved in the program and that the buses, taken together, have surpassed 1 million kilometers of service and carried more than four million passengers.[4]

### Japan

Toyota, in conjunction with Hino Motor, began fuel cell bus development in 1991. Since then it has produced several buses. Toyota is using a hybrid configuration with technology developed for the Toyota Prius car. Between August 2003 and September 2004, a fleet of four buses travelled a cumulative 25,000 kms on demonstration in Tokyo.

Led by Japan's Ministry of Economy Trade and Industry (METI), over 20 automobile manufacturers and energy companies are partnering to provide hydrogen produced from a variety of sources for fuel cell vehicles in operation throughout Japan. Currently 58 vehicles and 10 hydrogen fueling stations are operating in the Tokyo Metropolitan area as part of the Japan Hydrogen and Fuel Cell Project (JHFC)

On January 31, 2005, Toyota announced that it would deliver eight fuel cell buses for use at the Aichi Expo between March and September 2005. Although this is the world's largest fleet demonstration to date, the buses were used simply in a shuttle capacity carrying visitors within the exposition site itself.

### Brazil

Ballard Power Systems is a member of a consortium that has been invited by the UNDP/GEF to develop a proposal for the implementation of Phase II of a UNDP/GEF fuel cell bus project for Sao Paulo, Brazil. While the consortium proposal is not in the public domain, it is understood a prototype fuel cell hybrid bus will be developed in 2005/06 and eight buses will be delivered in late 2007. Speaking on the UNDP/GEF project at the last International Fuel Cell Bus Workshop (Porto, 2004), the representative from Brazil indicated that following successful completion of the eight bus demonstration in 2012, funding would be sought for a project that would see up to 100 fuel cell buses operating from a single garage.

CHINA

China has set hydrogen and fuel cells as a technology priority - 15% of the funding for the tenth Five Year Plan (2001 - 2005) was devoted to energy research and development, with 40% of this set aside for electric vehicle and hydrogen and fuel cell research. A key project being supported is the Beijing Hydrogen Transportation Partnership and Demonstration Park.

Hydrogen and fuel cell bus showcases are tied to two events China is hosting in the near future: the 2008 Olympic Games and the 2010 World Expo in Shanghai. With an eye to those events, China aims at a series of technical breakthroughs and key industrial developments:

- 2008: establishment of a technical platform for PEM[††] fuel cell and relevant vehicle power system
- maturing of core technologies through technical development and commercial demonstration
- market entry by 2015 of a hydrogen-fueled dynamic system for PEM-FC vehicles, cost competitive to conventional systems in mainstream applications.

GEF has approved a five year, US$32 million project ($12 million in UNDP/GEF funding plus $20 million in Chinese government contributions) to demonstrate six fuel cell buses each in Beijing and Shanghai, as well as hydrogen refueling in each city. The aim of this project is to help accelerate the cost-reduction of fuel-cell buses for public transit applications in Chinese cities. Hybrid technology will be encouraged. Bus delivery is scheduled for the third quarter of 2006, with buses in use through 2009. General Motors and Shanghai Automotive Group will be bidding.[5]

As well as advancing fuel cell cooperation between General Motors and Shanghai Automotive for bus applications, China has also encouraged the development of its own technology. In 2004, the fuel cell developer, Shanghai ShenLi, and Tsinghua University teamed up to develop a fuel cell bus that was showcased at the 2004 Hyforum in Beijing.

Ballard has provided three fuel cell powertrains to DaimlerChrysler to power three Citaro fuel cell buses that will enter revenue service in Beijing later this year. The RFP for the balance of the UNDP/GEF program (nine buses) is anticipated to proceed in late 2005.[6]

In September 2005, Ballard Power Systems hosted Chinese President, Hu Jintao, and his delegation for an official visit that included tours of Ballard's research, development and manufacturing facilities and an opportunity to ride in a Ballard-powered Ford Focus fuel cell car. The visit provided Ballard with an opportunity to showcase its technology and its manufacturing capability.



†† Proton exchange membrane

## United States

Two fuel cell bus demonstration programs are included in the 2005 Energy Policy Act. The bill creates a US$50 million program to demonstrate up to 25 fuel cell transit buses and infrastructure in five locations over five years. The second program is to develop and demonstrate fuel cell school buses. A total of $25 million has been authorized for this program during the period from 2006 through 2009.[7]

The energy bill is an authorization bill only so does not provide funding. It sets out programs and funding levels that Congress has agreed should be appropriated through annual spending bills; however those annual spending bills are subject to modification through the U.S. political process.

In February 2000, the California Air Resources Board confirmed its continued commitment towards reducing emissions from public transportation by establishing a fleet rule for transit agencies, more stringent emission standards for new urban bus engines and promoting advanced technologies by adopting zero-emission bus (ZEB) demonstration and ZEB acquisition requirements. In addition, the Board directed staff to review ZEB technology and the feasibility of implementing the purchase provisions of the program.

The ZEB purchase requirement startup depends on the compliance path selected and is only applicable to larger transit agencies (more than 200 buses).

For transit agencies on the diesel fuel path, a 15 percent aggregate total of all bus acquisitions from model years 2008 through 2015 must be ZEBs. For transit agencies on the alternative fuel path, the ZEB acquisition requirement starts with model year 2010 and runs through model year 2015. Transit agencies on the diesel path must submit a compliance plan by January 2007, while transit agencies on the alternative fuel path must submit a compliance plan by January 2009. Transit agencies selected fuel cell powered buses as the technology most likely to meet both desired performance characteristics and environmental goals.

At the time the bus regulation was developed, information available indicated that the research and development of fuel cells in transit buses would lead their development before their application in light duty vehicles. Buses are better suited to handle the relatively larger size and weight of fuel cells and on-board fuel storage. In addition, the development of fuel cells in a controlled fleet application would allow fueling and services requirements to be performed at a single facility, thereby helping to manage infrastructure and support challenges in the early years.

California Fuel Cell Partnership members began a program in 2004 to demonstrate seven fuel cell electric buses in regular transit service at Alameda Contra Costa Transit, SunLine Transit Agency and Santa Clara Valley Transportation Authority.

Additional buses may be delivered to Delaware, Washington DC, Las Vegas and Alabama. On December 27, 2004, the New Haven Clean Cities Coalition and the Greater New Haven Transit District announced funding for up to two fuel cell buses.

## Lessons Learned from Global Activity

In November 2004, representatives of countries engaged in fuel cell bus demonstrations gathered at the Second International Fuel Cell Bus Workshop and exchanged information on fuel cell bus issues including planned fuel cell bus demonstration programs in Japan, Brazil, China and the United States. Updates presented at that meeting confirmed both the move to next generation hybrid systems and the lack of progress on fleet expansion beyond individual bus demonstrations. It was determined that no single site currently identified will demonstrate more than eight fuel cell buses through 2012.[8]

The particular challenges presented by a conservative bus market internationally – limited governmental engagement with the transit industry on fuel cell technology and common lack of resources for all market players (technology developers, bus builders and end-users) - has resulted in fuel cell bus projects that continue to be limited in scale (three to eight units) and episodic in nature.

## The Lesson of Light Duty Programs

Meanwhile, multiple stakeholders across the hydrogen energy and fuel cell product value chain in Canada, the United States, Europe and Japan have endorsed light-duty automotive fuel cell demonstration partnerships with governments; for example the California Fuel Cell Partnership and the Hydrogen Infrastructure Demonstration and Validation Project in the United States; and the Clean Energy Berlin project in Germany.

BC Transit is currently using a hydrogen fuel cell-powered car supplied by the Vancouver Fuel Cell Vehicle Program, a partnership including Ford Motor Company, Fuel Cells Canada, the Government of Canada and the Province of British Columbia to gain direct insight into the requirements for successful operation and fueling of hydrogen fuel cell-powered vehicles.

Light-duty fuel cell vehicle developmental pathways are being identified which will see vehicle fleets building in numbers towards critical volumes operating in a limited number of locations, such as the "Lighthouse projects" advocated by GM and Shell. These projects will create networks of fueling stations in specific cities or regions of the country that offer both traditional and hydrogen fueling.

Similar effort is required to eliminate the barriers to full-scale deployment of heavy duty applications in fuel cell buses. Technology providers and transit systems have identified the need for an initial market of sufficient size to justify the investment in further development of hybrid fuel cell engines, systems and bus platforms and the scaling-up of production. This will bring the price of fuel cell buses to commercial levels if the incremental initial production cost is funded in part through multilateral or bilateral support by governments.

Industry intelligence indicates that the main providers of fuel cell drive systems and bus platforms envisage controlled demonstrations of up to 100 buses in three or four sites as being of sufficient scale to meaningfully advance the next generation hybrid technology towards commercialization.

## Need for Continued Government Support in Canada

*"Canada's strategy must find ways to promote technology solutions and prepare now to capitalize on our leading edge research and development capabilities in the areas of fuel cells and other energy efficiency technologies."*

**Canadian Vehicle Manufacturers Association**; Discussion Paper on Canada's Contribution to Addressing Climate Change", June, 2002

The transition to a hydrogen economy will be a long and capital-intensive process, and will need a sustained political will to realize the benefits of cleaner air, lower greenhouse gas emissions, the diversity of feedstock fuels for hydrogen and to capitalize on global market opportunities.

Canada has led the development of fuel cell drive systems, ancillary systems and bus platforms. An opportunity exists for Canada to demonstrate its leadership in fuel cell bus development and reap commercialization benefits by supporting a large-scale fuel cell bus deployment at home. If begun in 2006, a project of this scale will support and endorse the Hydrogen Highway™ initiative and be able to be showcased at the 2010 Games.

This initiative, if supported by governments, can create the market-pull necessary to attract additional private sector investment in fuel cell hybrid drive systems and bus platforms. This investment, together with strategic long-term government policy-making, will create an environment that accelerates cost reduction for applications in both buses and cars and enables the technology to become commercially available more quickly.

# Chapter 2:

## The Road Less Travelled: Rationale for Vision

*"By exploiting Canadian technology leadership, the fuel cell and hydrogen sector will create many high value added jobs, and increase our export strength, while at the same time providing a major reduction in urban air pollution and greenhouse gas emissions"*
**Ron Britton**, former President, Fuel Cells Canada

### Public Policy Drivers

It is the stated desire of Canada, as evidenced in public policy pronouncements, to address climate change through reduction of greenhouse gas emissions and enhance Canada's market reach for made-in-Canada innovative technologies.

As the UNDP has noted, once fully commercialized, fuel cell bus technology can play an important role in the stabilization of greenhouse gases by 2100 as represented in various scenarios developed by the Intergovernmental Panel on Climate Change (IPCC).[9]

### Climate Change

#### The Global Driver

The International Energy Agency (IEA) projects that over the next 20 years energy demand growth in transport will be greater than in all other end-use sectors. Despite efforts to use alternative fuels, oil will continue to dominate the sector. It anticipates that transport will account for more than half the world's oil demand in 2020.

Besides the energy security and sustainability implications of this dependence on oil, transport will also generate roughly one-fourth of the world's energy-related $CO_2$ emissions. The IEA also projects that growth in oil use and greenhouse gas (GHG) emissions from developing countries will far outstrip that from the developed world over the next 20 years. Oil use in transport is expected to grow three times faster in developing countries than in Organization for Economic Cooperation and Development (OECD) countries.[10]

Within five years, half the world's population will live in cities. By 2030, the urban population will reach 4.9 billion - 60% of the world's population. Nearly all population growth will be in the cities of developing countries, whose population will double to nearly 4 billion by 2030.[11]

Fuel for transport accounts for some 32% of final energy use.  Almost all of this energy is in the form of oil and transport accounts for approximately half of total oil usage. Of this, road transport accounts for 83 per cent.[12]

The future of the Kyoto Protocol on Climate Change is largely in the hands of the world's biggest contributors to greenhouse gas emissions.

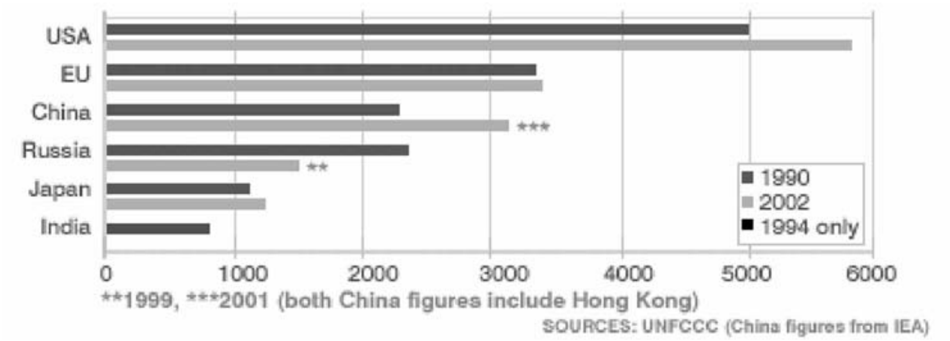



**FIG. 2.1** $CO_2$ EMISSIONS (MILLION METRIC TONNES)

Between 1973 and 2003 transport use increased from 42.3% to 57.2% of world oil consumption (720.64 Mtoe# to 1265.23 Mtoe). Carbon dioxide emissions from coal, gas and oil rose from 15.6mt to 25.0mt in that same period.[13]

In 2002 alone, $CO_2$ emissions from fuel combustion rose by 2%. The regions that contributed most to the 1990 - 2002 increase in world energy-related $CO_2$ emissions were China, OECD North America and other Asian nations. The transport sector is now the second largest source worldwide (24%) next to public electricity and heat production (35%).[14]

The G8 Communique on Climate Change signed at Gleneagles in 2005 stated both concerns and actions endorsed by the G8 members. Key points include:

- increased need and use of energy from fossil fuels, and other human activities, contribute . . . to increases in greenhouse gases
- energy demand will increase by 60% over the next 25 years
- reducing pollution protects public health and ecosystems
- the world's developed economies have a responsibility to act
- decisions being taken today could lock in investment and increase emissions for decades to come, it is important to act wisely now
- while uncertainties remain in our understanding of climate science, we know enough to act now
- we will encourage the development of cleaner, more efficient and lower emitting vehicles and promote their deployment . . . in areas including cleaner gasoline and diesel technologies, biofuels, synthetic fuels, hybrid technology, battery performance and hydrogen powered fuel cell vehicles.[15]

# Metric tonne equivalent

### Kyoto Protocol and Canada's Greenhouse Gas Emissions

In December 1997, Canada and more than 160 other countries met in Kyoto, Japan, and agreed to targets to reduce GHG emissions. Canada ratified the protocol arising from this agreement (The Kyoto Protocol) in December, 2002 and it became International Law on February 16, 2005.

The Canadian target is to reduce its GHG emissions to six percent below 1990 levels by the period between 2008 and 2012, comparable to the targets agreed to by its major trading partners.

Transportation is the largest single source of GHG emissions in Canada. In the transportation sector, GHG emissions are growing rapidly and, without further action, they could rise 32 per cent above 1990 levels by the year 2010, and 53 per cent above by 2020. Measures to slow the growth in transportation GHG emissions will be a key element in achieving Canada's GHG emissions target under the Kyoto Protocol.

In 2003 passenger transportation in Canada accounted for 93.5mt of GHG emissions by end-use, of which buses accounted for 3.7mt.[16]

There is a need for innovative solutions to urban sprawl, congestion and the harmful effects of transportation on Canada's environment - all of which place our economy, health and quality of life at risk. Canadians must begin having transportation choices that are more sustainable, whether they involve urban infrastructure, advanced technologies or policies on land management and congestion mitigation. Moreover, a carefully designed approach to achieving Canada's climate change commitments can help to advance a number of important public policy objectives.

Policy decisions to reduce $CO_2$ in the transportation sector will help improve the air quality in our cities, reduce traffic congestion and improve the quality of life as well as enhance the reputation of Canada's innovative industry to provide solutions to those problems. The aggressive development and use of technologies that are now being commercialized, such as fuel cell buses, can open markets for world-leading Canadian innovators.

## Global Competition for Hydrogen and Fuel Cell development

### Government Strategies

Governments worldwide acknowledge the public policy benefits in deployment of hydrogen and fuel cell technologies by investing in research and demonstrations, creating incentives, and conducting educational and outreach activities. National and regional governments have adopted strategies and incentives to accelerate the adoption and deployment of hydrogen and fuel cells. Canada must keep pace or lose its commercial advantages that come with international leadership. This is the competition.

In 2005 Canada ranked 14th in the World Economic Forum's Growth Competitiveness Index and Business Competitiveness Index. Countries with significant hydrogen and fuel cell development initiatives that have recognized Canada's strengths in this sector all ranked higher in both these indices. Other countries pursuing strategic initiatives in hydrogen and fuel cells without domestic technology strength in this area also ranked higher.[17]

Multi-year government budget allocations have been earmarked in the United States, the European Union, Japan, Korea and China. Dedicated national programmes are also in place in European countries such as Germany and Italy.

According to the International Energy Agency (IEA), countries as a whole are devoting something like $1 billion each year to government funded hydrogen and fuel cells programmes in IEA countries[18]. More than half of this is earmarked for fuel cells. Meanwhile, it is estimated that the private sector's own widespread activities are investing $3-4 billion annually[19]. Stakeholders include oil, gas and coal companies, process gas producers, power plant manufacturers, electric power utilities, motor manufacturers, producers of fuel cells, chemicals and high-tech components.

A very wide diversity is observed in the structure of national R&D programmes, which range from fully-integrated, public-funded efforts to national strategies bringing together both public and private-sector initiatives. Many nations are seeing a need to revisit their energy strategies, placing a stronger emphasis on hydrogen and fuel cells. Long-term programmes, coupled with international initiatives, are ensuring sustained commitment to this approach.

*Europe*

The European Union (EU) structures its support to hydrogen and fuel cells in a series of multiyear Framework Programmes. Its level of support from the Second Framework Programme (FP2) (1994) to the Sixth Framework Programme (FP6) (2007) increased from 8 million€ (Cdn $11.3 million) to 250 million€ ($353.2 million). The European Commission unveiled its plans for the Seventh Framework Programme (FP7) on 6th April 2005 and proposed a budget of 73 billion€ (Cdn $103.1 billion) over seven years (2007 to 2013)[20].

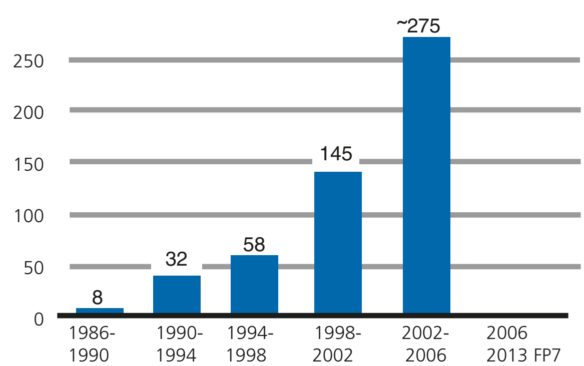



**Fig. 2.2** Hydrogen and Fuel Cell Research Effort in the EU

The European Hydrogen and Fuel Cell Technology Platform Strategic Overview, June 2005, provides an overview of current strategic priorities for the EU, including the development of "Lighthouse Projects", highlighting transportation projects.[21]

The Commission has identified six priority areas where public-private partnerships could be established to boost industrial competitiveness under FP7 via the Joint Technology Initiative (JTI). Hydrogen and fuel cells are listed as the first priority.

The goal of the proposed JTI is to deliver robust hydrogen and fuel cell technologies developed to the point of commercial take-off in 2015, with a view to large-scale mass market rollout by 2020, for transport applications; and to provide the technology base to initiate market growth for stationary fuel cell domestic and commercial and portable applications from 2010-2015.

Subject to on-going negotiations over EU budgets, the Commission has indicated it might be possible for it to contribute around 90 million€/year to 250 million€/year (Cdn $125 million to $353.2 million) public funding identified as being required by the European hydrogen and fuel cell technology platform. This, and any other public sources of funding that can be leveraged, should at least be matched by private investments in JTI projects.

### *United States*

*"We envision a future in which hydrogen serves, along with electricity, as a primary energy carrier for the U.S. economy"*

**Hon. Richard M. Russell**, Associate Director, Office of Science and Technology Policy; Office of the President of the United States of America, July 27, 2005

In his 2003 State of the Union Address, President Bush announced a $1.2 billion Hydrogen Fuel Initiative to reverse America's growing dependence on foreign oil by developing the technology needed for commercially viable hydrogen-powered fuel cells - a way to power cars, trucks, homes, and businesses that produces no pollution and no greenhouse gases. Through partnerships with the private sector, the President's Hydrogen Fuel Initiative seeks to develop hydrogen, fuel cell, and infrastructure technologies needed to make it practical and cost-effective for large numbers of Americans to choose to use fuel cell vehicles by 2020.

The Hydrogen Fuel Initiative's overarching goal is to enable industry to make a commercialization decision by 2015. Hydrogen is seen as being key to any USA energy future. Fuel cells still seem to be a technology with enough cachet to attract large quantities of research funding.

For 2005, the United States has approved spending for non fossil fuel research and development of US $587 million. Of the $325 million allotted to renewable energy, $100 million will be going to hydrogen and fuel cell projects. The budget for distributed power systems, which includes R&D into fuel cells, totals just over $77 million.[22]

With respect to transportation applications of hydrogen fuel cells, the strategic importance of these technologies to the United States was identified in a 2003 report to the Office of Technology Policy, US Department of Commerce: *Fuel Cell Vehicles: Race to a New Automotive Future*.[23] It states that fuel cell technology has the potential not only to transform the automotive industry but to help meet the increasing electricity demand of the twenty first century. It also confirms the belief that fuel cells will appear in fleet applications (buses and taxis) prior to adoption in private auto markets.

In July 2005, the U.S. Congress passed a five-year Energy Policy Bill, laying out the federal government's energy programs, funding priorities and tax policies for fiscal years 2006 through 2010.

The Energy Policy Act of 2005 takes important steps toward fostering the development of hydrogen fuel cell technologies. It includes more than $3.5 billion (Cdn $4.1 billion) for hydrogen and fuel cell related programs, as well as tax credits and other financial incentives.

### *Korea*

South Korea, alongside Japan, is making a very "loud" commitment to both hydrogen and fuel cells. Korea has published a detailed hydrogen economy roadmap which takes it a further step towards achieving its target of being the third largest fuel cell R&D player in the world. If achieved, this would place Korean R&D, in terms of funding, ahead of countries such as Germany and Canada – traditionally very strong players in this area.[24] Korea has declared a development goal to be 5% dependent on alternative energy by 2010 with hydrogen being selected as one of the key energy drivers.

From 1989 to 2004 the Korean Government spent US $10 million and $54 million on hydrogen and fuel cell research respectively. Budgets established for the period 2004 to 2008 allot US $94 million and $237 million for hydrogen and fuel cells research and $175 million for demonstration and dissemination.[25]

The roadmap envisages the deployment of up to 100 buses by 2008 and 5,000 buses by 2012, although to date Korea has yet to demonstrate a full size fuel cell bus. Mobile applications of fuel cells by Korean companies have largely been through OEMs collaborating with off-shore fuel cell developers. Hyundai-Kia is a participant in the US DOE technology validation program "Hydrogen Fleet and Infrastructure Demonstration" with Chevron and UTC Fuel Cells.

### *Australia*

Australia is committed to build on its STEP demonstration and expand its commitment to hydrogen and fuel cell participation. Recent discussions at the Fuel Cell Bus Club meeting confirmed initial actions for a federal Australian Fuel Cell Bus program with the objective of deploying a significant fleet of hydrogen and fuel cell buses. This initiative is tied to Queensland hosting the World Hydrogen Energy Conference in 2008 and to an election commitment made in October 2004 by the Liberal Party:

"build on the Perth trial, and invest $67 million (Cdn $59 million) over three years, from 2005-06, as the Commonwealth's contribution to the cost of hydrogen fuel depots in Australian cities and the purchase of up to 90 hydrogen buses".[26]

### *Japan*

Japan has ambitious "expected targets" for fuel cell vehicle deployment of 50,000 vehicles in 2010, 5 million in 2020 and 15 million by 2030. The METI budget for fuel cells has risen from 11.7 billion Yen (Cdn $118.4 million) in 2001 to 35.9 billion Yen (Cdn $363.2 million) requested for 2006.[27]

### *China*

Most of China's funding support is through the "863 program", which aims to enhance China's international competitiveness and improve China's overall capability of R&D in high technology. During the 10th Five-Year Plan (2001-2005) China's Ministry of

Science and Technology (MOST) approved a 880 million Yuan (Cdn $125.1 million) research and development "863 program" to develop advanced hydrogen technology, hybrid-electric drive and fuel cell vehicles.[28]

### Canadian Perspective

*"Some sectors – nanotechnology, ICT, environmental technologies (hydrogen fuel technology cluster) – have applications across the economy. Our goal is to ensure that competitive strengths in these areas provide cascading competitive benefits across the economy."*
**Hon. David Emerson**, Minister of Industry, Toronto, ON, September 21, 2005

### Urban Transit as Early Adopter of Hydrogen Fuel Cell-Powered Buses

*"Bus fleets are being seen as a good early market for fuel cell and hydrogen technology for reasons such as central refueling, predefined routes, high public visibility, size and … more design space for hydrogen storage tanks"*
**Kerry-Ann Adamson**, Fuel Cell Today, November, 2004

Early on in the development of hydrogen fuel cell technologies for mobile applications, urban transit systems were seen as a natural early adopter of this zero emission technology. Reasons include:

- urban transit buses currently consume a large quantity of fossil fuel each year - in Canada, 380 million litres of diesel and 17 million cubic metres of natural gas – and are thus a major source of greenhouse gases
- transit application is visible to a public sympathetic to improving air quality, especially in compromised air sheds
- buses do not have the same weight and space constraints as light duty vehicles so are more adaptable to alternate power systems
- transit properties have centralized facilities and governance structure that can more easily accommodate and manage the introduction of new fuels and technologies that serve public policy agendas
- transit buses are seen as an efficient mover of people; some 2.5 billion riders in Canada per year
- number of buses needing replacement over the next ten years total 7,000
- innovative policies, technologies and services that can "green" urban transit in Canada have global market significance

### Fuel Cell Bus Study Recommendations

In 2005 the CTFCA released a study that looked at issues facing Canada's urban transit systems in making the transition from the diesel-powered fleets of today to hydrogen fuel cell-powered fleets of the future. Key findings of that study include:

- commercial fuel cell-powered buses are expected to equal or surpass existing operational standards of diesel buses
- the reliability of commercially available fuel cell-powered buses is expected to be equal to or better than conventional diesel buses
- fuel cell hybrid buses – that use less hydrogen and have a smaller fuel cell stack than pure fuel cell systems – may enter the transit market place first
- maintenance operations, skills mix, facilities and tooling will need to be adapted considerably to accommodate a fuel cell-powered fleet
- handling and storage of hydrogen in urban transit system (UTS) facilities will involve procedures similar to practices for fuels like CNG
- hydrogen fueling procedures will not change noticeably from diesel fueling procedures
- capital costs of hydrogen fuel cell-powered buses are expected to be at least triple the cost of a diesel bus in the short term
- lifecycle cost will be the same and maintenance costs will be 15 to 20% less
- hydrogen technologies are expected to be price competitive in terms of the cost of fuel
- a significant collaborative effort involving all stakeholder groups is imperative if there is to be a successful transition to fuel cell-powered bus fleets in Canadian UTSs.

Fifty recommendations were made to stakeholders (Canadian UTSs, bus manufacturers, fuel cell system suppliers, hydrogen fuel storage system suppliers, hydrogen fuel and fueling system providers, training institutions and governments). Recommendations germane to BC Transit's proposed purchase of 20 fuel cell buses are that:

- all stakeholders continue participation in cost shared demonstration programs
- bus manufacturers, fuel cell system suppliers, fuel and fueling suppliers work collaboratively to ensure efficient integration of fuel cells and fuel storage and supply into bus design and operation
- governments continue to support the transition to hydrogen fuel cell-powered bus fleets through financial incentives
- governments target smaller UTS operations to encourage early adoption of hydrogen fuel cell-powered bus fleets[29]

## BC Transit as Champion

*"A pre-commercialization" project, that places sustained, long term demand on operations, maintenance and fueling activities, is the next logical step from small scale demonstrations"*
BOB IRWIN, FORMER PRESIDENT, BC TRANSIT

BC Transit is the provincial Crown Corporation charged with coordinating the delivery of public transportation throughout British Columbia outside Greater Vancouver.

BC Transit has been at the forefront of Canadian UTSs in identifying and adopting innovative technology and alternate fuels to maximize efficiency and reduce harmful emissions. In fact, the first ever fuel cell-powered bus, the "Ballard Bus," was demonstrated by BC Transit as early as 1992. A further demonstration of three fuel cell buses was conducted by BC Transit from 1998 to 2000.

Fiscal Year 2004 / 05 saw an increased focus on a range of new technologies and systems designed to promote efficiency and effectiveness, and to reduce the environmental impacts of urban transportation:

- BC Transit participated in a six-month pilot test of biodiesel to gain more first hand insight into the fuel efficiency, emissions and other impacts of a B20 blend (20% bio-fuel / 80% diesel)
- BC Transit purchased Canada's first production hybrid diesel-electric transit buses. Three buses are now in operation in each of Kelowna and Victoria
- BC Transit took advantage of an opportunity to use a hydrogen powered fuel cell car supplied by the Vancouver Fuel Cell Vehicle Program, a partnership including Ford, Fuel Cells Canada, the Government of Canada and the Province of BC to gain further insight into the requirements for successful operation and fueling of hydrogen fuel cell powered vehicles.


FUEL CELL VEHICLE, MARCH 31, 2005

BC Transit's mission statement integrates the Corporation's purpose, products and client base: "*To excel in the provision of safe, reliable, cost-efficient and market-focused public transportation systems that support the social, economic and environmental goals of the customers and communities served."*

BC Transit strives to ensure that the wide-ranging benefits of public transportation — access to jobs, education and health care; reducing transportation infrastructure and traffic congestion costs; contributing to improved air quality; and enhancing community and regional development — are realized to the fullest extent possible.

One of BC Transit's stated goals in its Service Plan is to:

> *Plan and deliver transit services that meet local land-use and growth priorities, while furthering the development of safe, healthy communities and a sustainable environment.*

An objective of that goal is to:

> *Identify and adopt new technologies to enhance customer service, environmental quality and transit's community benefits*[30]

Core values include:

- fostering innovation in planning, fleet procurement, service delivery, customer service and administration
- utilizing sound financial practices, and a competitive procurement process to ensure the highest value is received for dollars spent
- showing environmental stewardship through responsible purchasing practices and facilities management
- support for community agencies encouraging environmentally responsible transportation

### British Columbia: Environmental Commitment and Innovation

*"Our goal is to develop the hydrogen and fuel cell sector to make British Columbia the world's leading hydrogen economy by the year 2020."*
**Premier Gordon Campbell**, June, 2003

British Columbia is recognized internationally for its natural splendour and its citizens' concern to protect the environment while making it accessible to the world.

*1. The government will continue to implement the B.C. Energy Plan, which promotes alternative energy and investment in conservation and energy*

*2. An industry advisory group is helping to prepare a strategy to ensure that BC remains a leader in the development of hydrogen and fuel cell technology.*

*3. The government will enhance energy conservation and alternative energy with a comprehensive energy strategy and facilitation of technology road map's for hydrogen and bioenergy.*

*6. Climate change will be incorporated into B.C.'s transportation planning and investment strategies.*

*7. A provincial transportation demand management initiative will also address greenhouse gas reduction. Government will work with partners to enhance public transit, reduce congestion, and identify other ways to move people more efficiently.*

*9. The government will consider further incentives to encourage the purchase of alternative fuels and hybrid vehicles.*

This was a commitment reflected in the Olympic Games bid by the Vancouver Bid Committee. A major theme of the successful bid was to make the 2010 Games venues and operations as sustainable as possible. Specific to transportation, themes 4 and 14 from the Bid Book state:

*"Proven low and zero emission technology including hybrid, natural gas, electric and fuel cell vehicles are planned for use during the Games. Hydrogen fueling infrastructure necessary to support the use of fuel cell buses and vehicles is planned for Vancouver and Whistler. Installation of hydrogen fueling infrastructure will create a lasting community legacy that will accelerate transition to a zero emission transit system."* (Theme 4)

*"Vehicles and support systems will be focussed on clean and renewable sources of energy. Vancouver 2010 has brought together world-leading transportation organizations to build a more sustainable transportation system for the 2010 Games. The systems will be technically proven, safe, reliable, efficient and accessible and will use alternative fuel and zero emission technology wherever possible."* (Theme 14)[31]

Building on British Columbia's commitment to developing its hydrogen and fuel cell industries in the 1990s, British Columbia continues to lead the country in its public policy vision related to alternative energy and innovative solutions to environmental problems. Accepting the social benefit and economic value of hydrogen and fuel cell contribution to cleaner air, BC industry, through the Premier's Technology Council initiative, prepared a Hydrogen Fuel Cell Strategy that holds as its vision for "British Columbia to have the world's leading hydrogen economy by 2020."[32]

Further to the release of this strategy, a vision for British Columbia's industrial cluster of power technologies has been developed. Within this Vision for Power Technologies, "Smart Transport" is identified as one of five key areas where British Columbia has a commercial advantage.

*27. The government will develop guidelines and performance targets for ministries and Crown agencies to acquire cleaner vehicles, fuels and transportation services.*

*28. The government will encourage ministries and Crown corporations to incorporate emission reducing policies and guidelines in their service plans.*

*35. Joint initiatives will be pursued with other jurisdictions where these initiatives support government objectives.*

*In addition, the Plan states:*

*"Hydrogen technologies can contribute significantly to future reductions of greenhouse gas emissions. The world's largest cluster of hydrogen and fuel cell companies is located in the province. The government is championing a Hydrogen Highway™ that will tie together research facilities while showcasing fuel cell vehicles, refueling stations and stationary power applications in the run up to and beyond the 2010 Olympic and Paralympic Winter Games"* [34]

*"British Columbia has the world's leading firms in smart urban transport solutions developing motors, engines and other vehicle systems that are leveraging new approaches to fuels. We are taking the lead in the fueling infrastructure of the future with world-class research and some of the world's high profile Hydrogen Highway™ showcase opportunities …"*[33]

Within this Vision, government procurement is identified as a critical action that can be taken to advance this opportunity. Accelerating local demand for innovative products and services through government procurement and incentives is seen as key to commercializing opportunities.

### British Columbia's Plan

British Columbia's Plan to address climate change – released in 2005 - is the result of extensive research and consultation with, among others, scientists, health officials, economists and everyday British Columbians. The Plan resulted in 40 actions, nine of which have relevance to BC Transit's fuel cell bus purchase proposal. (see insert p. 27 & 28 )

### Resort Municipality of Whistler

*"Whistler is committed to using the cleanest energy possible. Demonstrating new technologies is consistent with our resort community's vision, values and goal of moving towards sustainability"*
**Hugh O'Reilly**, former Mayor of Whistler

The Resort Municipality of Whistler (RMOW) is located approximately 120 kilometres north of the City of Vancouver, B.C. in the Sea-to-Sky (STS) corridor. This corridor extends approximately from the Howe Sound entrance at the Strait of Georgia to the confluence of the Pemberton and Lillooet valleys at Pemberton, B.C. The corridor traverses the Coastal Mountain Range and encompasses a coastal fjord, steep valleys, glaciated terrain, coniferous forest, and river valleys. Scenic vistas are among the corridors greatest attributes and the corridor is extensively used for recreation, tourism and other related activities.

The Resort Municipality of Whistler has committed to mitigating the negative environmental effects of unprecedented growth. Indeed, its continued commercial success depends on preserving the "Whistler Experience". Clean air is clearly an integral part of that experience.

For the next 15 years, the RMOW will be guided by an Integrated Energy, Air Quality and Greenhouse Gas Management Plan that was prepared in 2004. In research for that plan, it was determined that vehicles account for nearly half of the total GHG emissions in the community. As part of the plan, RMOW is committed to action that will, by 2020, see a transition in its transportation system to renewable energy sources, improved air quality and ecosystem integrity. Hydrogen fuel cell-powered buses will play a major part in this transition.

As host to the Nordic events of the 2010 Games, the community and environment of Whistler will be displayed to the world.

## GLOBAL MARKET OPPORTUNITY

*"China and India, as the pre-eminent developing economies … ought to benefit significantly from the efficiency improvements offered by fuel cells, and may be leaders in the rollout for mass markets.:*

**MIKE BROWN,** CHAIR, CHRYSALIX ENERGY LIMITED PARTNERSHIP, FEBRUARY, 2004

Rapidly increasing traffic congestion, air pollution, and sprawl are jeopardizing the ability of the developing world's premier cities to achieve or even approach sustainability. As stated by the Office of Technology Policy in the United States, "Most future growth in the vehicle market will occur not in already heavily industrialized countries such as Japan, Germany and the United States, but in industrializing countries such as China and India."[23]

The markets for transportation systems and advanced fuels infrastructure are predicted to grow, with some projections showing significant market adoption in selected applications by 2010, and widespread adoption of most applications by 2020.[35] The growing economies in India, China, and other Asian regions represent large, real, and imminent markets for clean transportation technologies. More importantly, the world's largest vehicle users (e.g. California) and the greatest potential users (e.g. China and India) are setting aggressive goals for alternative fuels penetration in the next decade (e.g. 10 and 20% of the total vehicular fleets, respectively). In addition, and quite independently of the chosen suppliers, these jurisdictions will require the expertise and know-how to ensure successful deployment and integration of all the technologies required to provide a complete service solution.

These problems, present in large urban areas of developing countries, also account for a substantial share of the expected increase in world oil use and $CO_2$ emissions over the next twenty years. The introduction of clean fuel cell bus fleets in these cities - before cars dominate - can help achieve transport sustainability. Compared to urban transport systems dominated by private vehicles, any bus-dominated system results in less traffic congestion, lower energy use and emissions, and improved mobility for all social and economic classes. Emerging fuel cell bus technology can dramatically reduce emissions and remove demand for oil use from buses themselves.

Transport drives oil demand and transport is growing three times faster in developing countries than in developed countries. Successful fuel cell bus fleet introduction would remove substantial amounts of oil from use in the large urban centres of developing countries, where transport demand is growing quickly. The collective impact of initiatives, such as fuel cell bus deployments to promote sustainable public transit, can be an important strategy to reduce world oil demand and greenhouse gas emissions.

# Chapter 3:

## Cleaner Passage: Benefits of Low Emission Public Transit

As described in the following sections, the local environmental and health benefits of clean transportation can be quantified in terms of reduced greenhouse gas emissions (e.g., tonnes of avoided $CO_2$ emissions per year), and lower pollutant levels per unit of service provided (kg of pollutant per km-passenger). However, the geopolitical and market benefits can be more significant than all the other benefits combined, especially if they solidify Canada's position as a world leader in sustainable transportation systems. The following sections describe the main areas of benefits and provide quantitative estimates related to the deployment of a fuel cell bus fleet in Whistler.

The energy system is the crucial link between human activity and global climate. Historically, all the energy sectors (and most notably surface transportation) have caused significant environmental damage, increased regional energy dependency, and promoted the adoption of business philosophies dependent on carbon-intensive sources of energy.

The adverse environmental effects of fossil fuel combustion have been extensively documented: initially poor local air quality, then regional acidification and, finally, global increases in the atmospheric concentrations of GHGs. These pollutants interfere with planetary energy flows and, by trapping infrared radiation, they have an overall warming effect.

### Climate Change

Climatic changes have occurred and could continue to occur in the absence of humans. However, most of the increase in temperature observed in the last century is attributable to human activity since the industrial revolution. The science behind this conclusion has been summarised in the Third Assessment Report (AR-3) from the Inter-governmental Panel on Climate Change (IPCC).[9] This report represents the work of 122 lead authors, 515 contributing authors, 21 review editors, and 420 expert reviewers from around the world. It is considered the most current and authoritative summary of the state of knowledge on climate change. This report and recent provincial publications are the main sources for the global and regional figures discussed in the following sections

#### Global Climatic Changes

The current state of knowledge indicates that the global average surface temperature has increased by about 0.6˚C in the 20th century. Globally, the 1990s were likely the warmest decade and 1998 the warmest year in the instrumental record since 1861. Recent observations and new analyses of proxy data for the northern hemisphere also reveal that the temperature increase in the 20th century has been the largest increase of any century during the last millennium (see Figure 3.1). The averaged surface temperature is projected to increase by 1.4˚C to 5.8˚C over the period 1990 to 2100. These rates of warming are higher than the observed rates during the 20th century, and they are without precedent in the last 10,000 years.

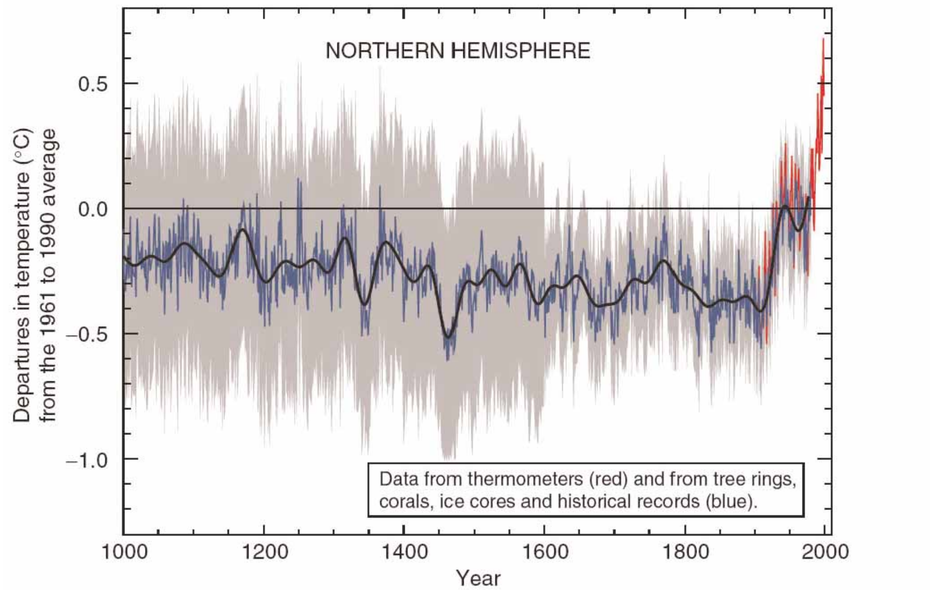



**FIGURE 3.1**: THE TEMPERATURE RISE IN NORTHERN HEMISPHERE IN THE LAST CENTURIES HAS BEEN THE LARGEST IN THE LAST 2000 YEARS. [9]

In addition to the gradual general trends, there have been changes in extreme weather conditions observed during the second half of the 20th century. These extreme events include higher maximum temperatures and more hot days per year, higher minimum temperatures, fewer cold days and frost days over almost all land areas, reduced diurnal temperature range, increase of heat index, increased summer continental drying and associated risk of drought, and increases in tropical cyclone peak wind intensities.

These changes in our climate can have repercussions of planetary scale. The human activity responsible for these changes is mostly associated with the release of greenhouse gases into the atmosphere (see Table 3.1).

| | $CO_2$ | $CH_4$ | $N_2O$ | CFC-11 | HCFC-22 | $CF_4$ | $SF_6$ |
|---|---|---|---|---|---|---|---|
| **Pre-industrial level** | ~280 ppmv | ~700 ppbv | ~275 ppbv | zero | zero | zero | zero |
| **1994 concentration** | 358 ppmv | 1720 ppbv | 312 §ppbv | 268§pptv | 110 pptv | 72§ pptv | 3-4 pptv |
| **Rate of increase *** | 1.5 ppmv/yr | 10 ppbv/yr | 0.8 ppbv/yr | 0 pptv/yr | 5 pptv/yr | 1.2 pptv/yr | 0.2pptv/yr |
| | 0.4%/yr | 0.6%/yr | 0.25%/yr | 0%/yr | 5%/yr | 2%/yr | ~5%/yr |
| **Lifetime (years)** | 50-200† | 12‡ | 120 | 50 | 12 | 50,000 | 3,200 |

**NOTES:**

$CO_2$ (carbon dioxide), $CH_4$ (methane), $N_2O$ (nitrous oxide), $SF_6$ (sulphur hexafluoride), and $CF_4$ (a perfluorocarbon, or PFC) are covered by the Kyoto Protocol.

CFC-11 and HCFC-22 (a CFC replacement) are also ozone-depleting substances and thus addressed under the Montreal Protocol rather than under the climate change agreements. 1 ppmv = 1 part per million by volume; 1 ppbv = 1 part per billion by volume; 1 pptv = 1 part per trillion by volume.

§ Estimated from 1992-93 data.

* The growth rates of $CO_2$, $CH_4$ and $N_2O$ are averaged over the decade beginning 1984; halocarbon growth rates are based on recent years (1990s).

† No single lifetime for $CO_2$ can be defined because of the different rates of uptake by different sink processes.

‡ This has been defined as an adjustment time which takes into account the indirect effect of methane on its own lifetime.

**TABLE 3.1:** CHANGES IN THE GLOBAL CONCENTRATIONS OF GREENHOUSE GASES.

The most important GHGs include carbon dioxide (from fossil fuel combustion), methane (from biomass decomposition), nitrous oxide, and mixtures of chlorofluorocarbons (CFCs), perfluorocarbons (PFCs), sulphur hexafluoride, and other gases.

The historical records (both measured and inferred from proxy measurements) indicate a very strong correlation between the increases in GHG concentrations above pre-industrial levels, and the observed changes in global surface temperature (see Figure3.2).

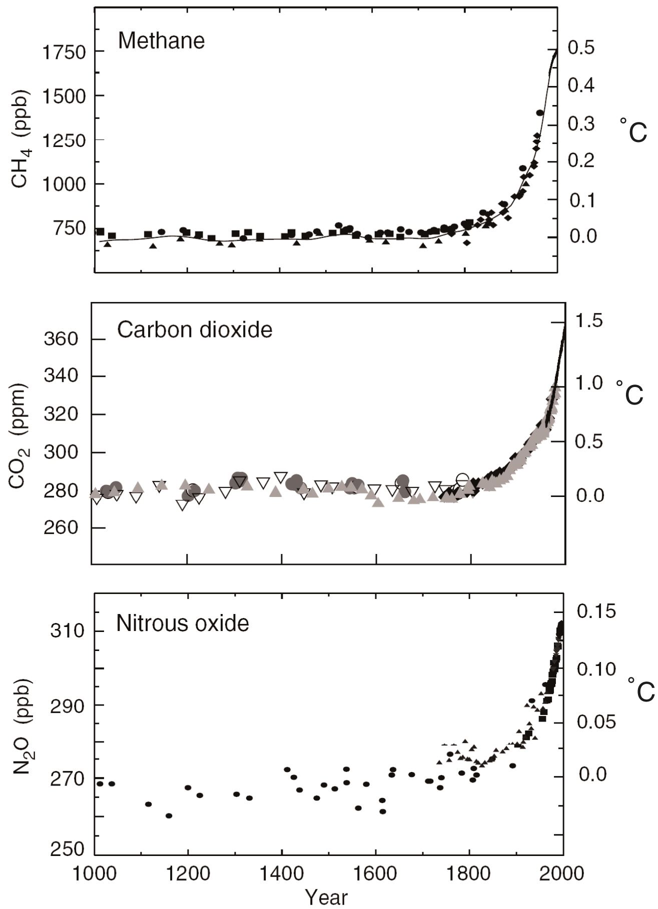



**Figure 3.2:** The historical concentrations of GHGs are closely related to the temperature increase in the Northern Hemisphere [9]

## Impacts on British Columbia

Specific to British Columbia, warming trends as a result of the Greenhouse Effect are shown in Figure 3.3. The provincial evidence linking the increase in emissions to climate change is consistent with the IPCC findings on a global scale.

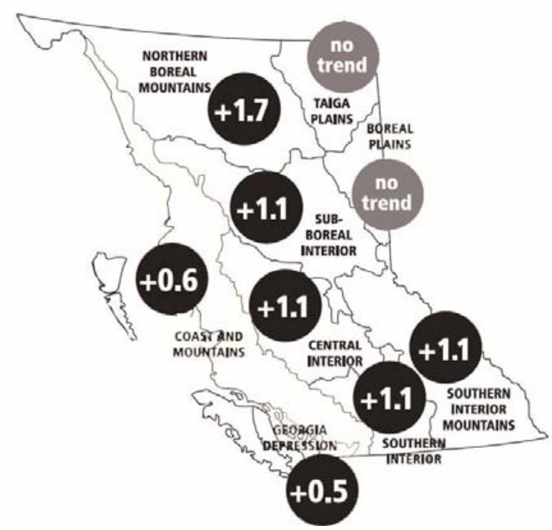



**Figure 3.3**: The temperature increase in average air temperature (°C per century) in the province[36]

In 1999 the total GHG emissions were 63.5 megatonnes of carbon dioxide equivalent: an increase of 10.8 megatonnes or 20% over nine years. The population increase accounted partially for the increase, but emissions from the transportation sector exceeded the population growth rate.

The transportation sector is the single largest source of GHG emissions in the province, accounting for 42% of the current total. [36]

The dramatic increase in emissions from the transportation sector resulted not just from an increase in the number of vehicles (total sales in 2000 were only 7% higher than those in 1990), but more importantly, from changes in the proportion (36%) of more inefficient vehicles in the commercial category (light trucks, SUVs and minivans). Like the global estimates, the provincial projections carry a lot of inherent uncertainty. However, some of the effects have already been observed.

### Fuel Cell Buses and GHG Emissions

Empirical data continue to become available as bus demonstration programs are implemented.[37] There is also a large body of knowledge on predictive models for the GHG emissions associated with full fuel cycle vehicle operation. One of the first models was developed by Delucchi between 1987 and 1993 (the Lifecycle Emissions Model or LEM). This model was updated in 1997 with recent data for motor fuel production, processing, distribution and use in the United States. A partial Canadian adaptation was completed by Delucchi for Natural Resources Canada in 1999. This updated version was used to develop GHGenius: a Canadian model used for several government and industrial studies between 1999 and 2004.

The fuel pathways considered in the model included ethanol from corn or wheat, ethanol from wood feedstocks, methanol for fuel cell vehicles, a variety of methods of producing hydrogen for fuel cell vehicles, biodiesel and ethanol blended diesel fuel pathways and mixed alcohol production. In 2001, Levelton and Delucchi expanded GHGenius to provide projections up to 2050, added Mexico to the model and added the capability of regional analysis for Canada and the United States.

The US Environmental Protection Agency (EPA) has also developed a software tool (MOBILE) for predicting gram per mile emissions of hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), carbon dioxide ($CO_2$), particulate matter (PM) and air toxics from cars, trucks, and motorcycles under various conditions. Environment Canada has adapted this model to include Canadian specific data (MOBILE6.2C). The updated emissions models incorporate improved understanding of on-road emissions and known future changes in emissions regulations.

One of the first steps in GHG emissions calculation is the normalisation of all the gas emissions to equivalent tonnes of $CO_2$. This normalisation is required because the same amount of different gases will have different overall warming effects on the atmosphere. For example, the effect of a tonne of methane (CH4) is 21 times larger than the effect of a tonne of $CO_2$. Similarly, Nitrous Oxide N2O has an equivalence factor of 310 compared to $CO_2$. In the following discussion, the GHG emission for different fuel cell fueling scenarios have been normalised to tonnes (or grams) of $CO_2$ (i.e., $tCO_2eq$ or $gCO_2eq$, respectively).

### GHG Emissions Costs

The base price for GHG emissions can be equated to the Canadian Government target value of \$15/tonne $CO_2$eq. However, the costs specific to GHG emissions can vary significantly and can be as high as \$300/tonne$CO_2$eq.[38] More importantly, the costs associated with the consequences of higher GHG concentration can be much larger than the costs ascribed to emissions under trading, permit or quota systems.

In a recent publication, the Association of British Insurers examined the financial implications of climate change through its effects of the three major storm types affecting insurance markets (hurricanes, typhoons, and windstorms).[39] The study concluded that for the most extreme events (i.e., storms occurring once every 100 or 250 years), the potential impacts by 2080 could include:

- \$100 to \$150 billion increase in wind related insurance losses in the US (due to hurricanes)
- \$25 to \$34 billion increase in losses due to extreme typhoons in Japan and
- \$32 to \$38 billion increase losses due to extreme European storms (all figures in US \$)

Other costs include increases in flooding costs (\$120 to 150 billion), and higher cost of the capital required by insurers (approximately 60% premium increases). These estimates do not include the likely increases in society's exposure to extreme storms (due to growing and wealthier populations).

## Fueling Scenarios in Whistler

The possible fueling pathways for Whistler were investigated in an extensive study released in May 2004.[40] This study used the MOBILE and GHGenius software, and included consideration of the BC Transit fleet in the Whistler area. Several full fuel cycle scenarios were considered, but scenarios for hydrogen generation from 100% natural gas reforming or from 100% hydroelectric power were not included. The reasons for this omission are unclear, but they are probably related to the available energy mix and the lack of a natural gas pipeline to Whistler at the time of writing. To make some of the conclusions more general and applicable to other jurisdictions (e.g., Victoria), figures have been included for these additional scenarios. These figures were collected from a recent economic analysis of various hydrogen fueling options in Canada.[38] In this case, the values (in $gCO_2eq$/km) correspond to a well-to-tank analysis on heavy duty vehicles The GHG emissions from different fueling pathways are compared in Figure 3.4.

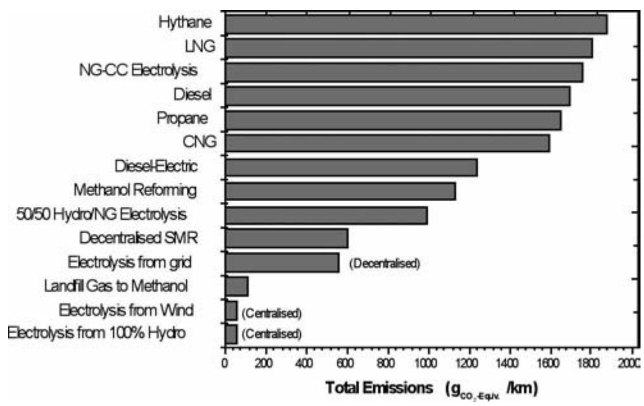



**Figure 3.4:** The full fuel cycle emissions associated with different fueling pathways for BC Transit buses in Whistler. Adapted, reviewed and modified from References. [38] [40]

These results are consistent with findings and calculations performed on light duty vehicles which also show that most of the hydrogen (fuel cell) fueling pathways result in reductions in the GHG emissions associated with a full fuel cycle.

## Costs/Savings of a Fuel Cell Bus Fleet in Whistler

The possible savings or costs (compared to diesel) have been calculated for all the fueling scenarios discussed in the previous section. To perform this calculation, the assumptions made are in Table 3.2.

| Fuel Cell Bus Fleet | | |
|---|---|---|
| Number of buses | 20 | Comments |
| km/yr | 60000 | |
| yrs of service | 20 | |
| Value of CO2 emissions (CAD$/tonne) | 15-300 | Price range |
| Average occupancy (passengers) | 25 | |
| Service (p -km/yr) | 1500000 | |
| National CO2eq target (Mt/yr) | 532.98 | i.e., 6% below 1990 |
| 2003 national emissions (Mt/yr) | 740 | |
| Deficit (Mt/yr) | 207.02 | Target is 270 |
| **Fuel Cell fuelling pathways** | | |
| LNG | Liquefied natural gas | |
| CNG | Compressed natural gas | |
| PROPANE | Low pressure liquefaction | |
| HYTHANE | Mixture of hydrogen and natural gas | |
| HYBRID | Diesel electric | |
| A | Natural gas/Combined Cycle Electrolysis | |
| B | Methanol decomposition | |
| C | Electrolysis with 50% Hydro/50% Natural gas | |
| D | Landfill gas decomposition to Methanol | |
| E | Electrolysis from 100% Hydro power | |
| F | Electrolysis from wind energy | |
| G | Electrolysis from grid electricity | |
| H | Decentralised Steam Methane reforming | |

**TABLE 3.2:** ASSUMPTIONS FOR THE CALCULATIONS IN FIGURE 1.5

The reduction in GHG emissions and the potential monetary savings are specific to a fleet of 20 fuel cell buses in the Resort Municipality of Whistler. The actual values upon deployment and implementation may differ from these calculations, but the trends will remain. Despite the significant challenges facing the new technologies, clean transportation systems based on hydrogen and fuel cells can help Canada meet its GHG emissions reduction targets.

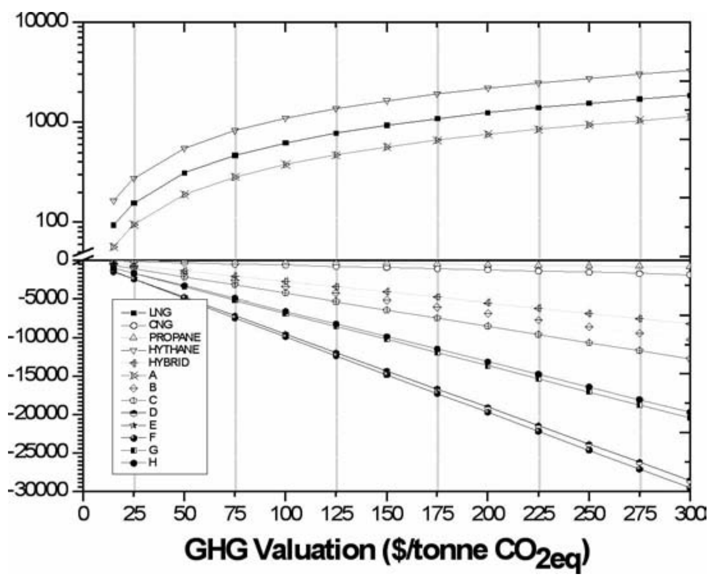



**FIGURE 3.5:** THE SAVINGS/COSTS ASSOCIATED WITH DIFFERENT FUELING PATHWAYS AS A FUNCTION OF GHG VALUATION.

## Health and Social Benefits of Clean Transportation

According to the World Health Organisation (WHO), an estimated 800,000 people per year die prematurely from cancer, cardiovascular conditions, and respiratory diseases caused by outdoor air pollution.[41] Other adverse effects include increased incidence of chronic bronchitis and acute respiratory illness, exacerbation of asthma and coronary disease, and impairment of lung function.

In Canada, two recent reports indicate that poor air quality is killing Canadians across the country.[42] In June of 2005, the Toronto Board of Health released a report on the influence of weather and air pollution on mortality.[43] Almost simultaneously, the Ontario Medical Association (OMA) released a report on the illness cost of air pollution.[44] In this report, the OMA estimated that almost 6,000 people in Ontario will die prematurely in 2005 due to exposure to air pollution. It also estimated that this number will rise to approximately 10,000 people by 2026.

### Health Impacts of Air Pollution in British Columbia

By Canadian and World standards, British Columbians enjoy good air quality. In general, the Interior, the North and the Fraser Valley experience higher pollutant levels than other areas of the province. However, and unlike Ontario, British Columbia has not undertaken a comprehensive study on the health effects of air pollutants.

The latest report from the Provincial Health Officer in British Columbia uses data from other parts of Canada (e.g., the Ontario estimates) and other international efforts. Based on these findings, the Provincial Health Officer has estimated that the health care costs of air pollution in British Columbia total some $167million/year[45] and can be approximated as follows:

- $85 million for outdoor air pollution
- $15 million for indoor air pollution
- $67 million for second hand smoke

More than 50% of this burden is attributable to outdoor air pollution and, in urban centres, a large fraction of this total is attributable to fossil fuel combustion.

Despite a large (>20%) decrease in emissions from 1985 to 2000, the smog present in the Lower Fraser Valley (LFV) is a continuing health concern in British Columbia. In 1985, the Greater Vancouver Regional District (GVRD) developed emission inventories to support an Air Quality Management Program in the LFV. Mobile sources account for 53% of smog precursors. Mobile sources include on-road and off-road vehicles. The 2000 LFV inventory indicated that light-duty and off-road vehicles now account for 83% of carbon monoxide emissions in the airshed. Motor vehicles may contribute as much as 40% of PM2.5 mass and 30% of light scattering particles. [45]

A large fraction of the Vancouver population resides in close proximity to roads with high vehicular occupancy (.e.g., 15,000 or more vehicles per day). Air quality data from traffic monitoring sites showed the largest differences from baseline levels of elemental carbon (a pollutant whose primary sources are diesel vehicles). The importance of diesel exhaust in relation to human residential exposure is proportionally greater than its contribution to air pollution.

The importance of a transition to cleaner transportation systems has triggered initiatives where British Columbia is showing national leadership. In September 2005, a new air quality index developed by a British Columbian Health Officer will begin testing in the Thompson Okanagan area. This new index will be the first in the world to consider the combined health effects of a group of pollutants as opposed to assigning individual indices to separate substances. If successful, the new index will be used across Canada. Combined with the nascent fuel cell and hydrogen industries clustered in British Columbia, the health and environmental expertise could make our province and Canada the world leader in the transition toward clean and sustainable transportation systems.

The estimates and models will vary as new data become available, but the general can be summarised by one of the conclusions in the latest report from the Provincial Health Officer [45 p.20]:

*"As our urban populations grow, we must come to recognize automobile pollution as a health issue now, and as a survival issue for the planet in the longer term. We need more attractive public transportation options and more innovative urban and work planning approaches that minimize dependence on private automobiles."*

### Summary of GHG and Health Benefits

The vehicles in the BC Transit fleet in Whistler share operations with vehicles in the Resort Municipaility of Whistler (RMOW) and the Whistler and Blackcomb Mountains. The overall fleet includes a wide variety of on- and off-road vehicles including snowcats. The special vehicle characteristics and fueling options were studied extensively in a recent report by Levelton Engineering Solutions [40]. This study is one of the main sources for the following discussion and calculations.

BC Transit operates 24 diesel-powered buses in Whistler (four operational spares). The bus fleet consists of 12 high-floor 35 ft buses meeting 1993 emissions standards (powered with Detroit Diesel two stroke 6V-92 engines), and 12 low-floor 30 and 35 ft buses meeting 2002 emission standards (powered by Cummins ISB engines). The fleet is expected to expand to 40 buses by 2010 resulting in a 67% increase in vehicles and the associated increases in GHG's. It is evident that Whistler does not have the luxury of proceeding into the future with business as usual. If it does, their baseline GHG emissions will rise by over 60%.

The current bus fleet consumes slightly less than 1,000,000 litres of diesel annually. Based on the consumption per km, the placement of 20 fuel cell buses into operation running a planned 75,000 km annually is expected to result in a GHG avoidance of 132 tonnes/yr per bus.

**GHG Benefits**

| **Buses** | **Tonnes/yr** | **GHG 20 year benefit (tonnes)** |
|---|---|---|
| 20 | 2657 | 53,140 |

Deploying and operating a fuel cell bus fleet in Whistler and Victoria will reduce GHG emissions and air pollution. Compared to the current diesel bus fleet in Whistler, each fuel cell bus could reduce mobile air toxic emissions by 100% and, depending on the fueling pathway, GHG emissions by up to 97%.[40]

# Chapter 4:

## The Road to Market: Opportunity of Early Adoption

*"Today, there is a global race toward commercialization of fuel cells and hydrogen . . . Long term leadership will be in the hands of those who move the quickest. The prize is immense economically, socially in terms of quality of life, politically in terms of energy independence and environmentally with an improved world . . ."*
**Firoz Rasul**, Chair, Ballard Power Systems
April 1, 2004

By promoting a planned transition to non-polluting transportation systems, Canada can enhance its leadership in the knowledge, logistics, and manufacturing innovation associated with fuel cell bus deployment around the world.

The 2010 Games provide an unprecedented opportunity to showcase these assets, and to attract the attention of a global market for fuel cells in general that could grow to billions of dollars per year (see Figure 4.1).[46]

### Market Growth Potential

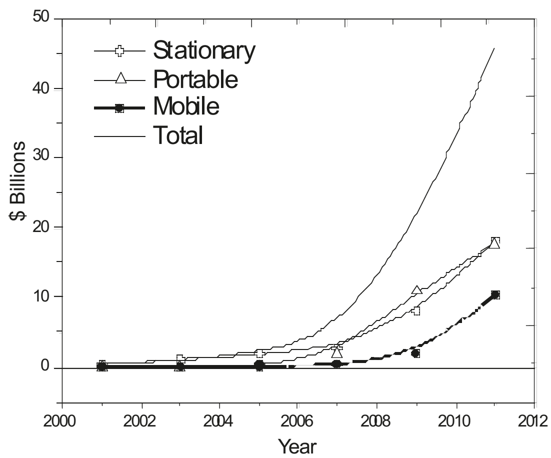



**Figure 4.1:** Global fuel cell systems estimated demand.

Markets for fuel cells are diverse and the revenue potential is substantial. PricewaterhouseCoopers (PwC) estimates the global market for fuel cells in all uses could total $46 billion by 2011. Approximately 25% of that amount would be for mobile applications. By 2021, they estimate the market at $500 billion to $2.5 trillion depending on how fast technologies are adopted.
Developed regions such as Europe, North America and Japan are expected to be the early adopters for reasons of:

- energy costs
- large consumer demand and willingness
- environmental pressures
- regulatory change

Much of the early demand is expected to come from institutional and government buyers willing to pay a premium to demonstrate the benefits for society and the environment.

The most recent PwC survey of the international fuel cell industry shows continuing growth in sales (up 41% to US $338 million), R&D expenditure (up13% to $859 million) and employment (constant at 7,748)[47]. In Canada alone, revenues are up 40%, intellectual property ownership through patents has grown by 34% and participation in demonstration projects of all kinds is up almost fourfold.[48]

### Bus Markets

While the individual passenger vehicle remains the biggest challenge to alleviate the health and environmental impacts of transportation, some of the more immediate opportunities are found in mass transit systems. The purchase of a fuel cell powered bus fleet has benefit and value to the community of Whistler and more broadly for Canada. There is a global market, particularly in crowded urban centres of the developing world, where public transit must be transformed from power sources that are highly polluting to cleaner power to secure not only their sustainability but survivability. This market dwarfs the North American transit bus market in terms of number of buses needing to be replaced.

Canadian leadership on fuel cell bus deployment is recognised around the world. Between 1991 and 2003 a number of demonstration projects were implemented in Canada, the US, and Europe. These demonstration projects continue to provide valuable empirical information on the operation, safety, and reliability of the related fuel cell and hydrogen technologies. However, the market opportunities and the value-added associated with providing a complete fleet deployment and operation solution can be substantial.

2004 bus data project that production volume of heavy duty diesel engines (9.8L and above) reached 832,000 units. Demand for buses greater than 12 tonnes is estimated to be as large as 105,000 units. Current bus sales total more than 57,000 units.[49]

### Canada's Bus Manufacturing Industry

In a 2002 report prepared for Transport Canada by the IBI Group the public transportation industry in Canada was identified as large and extensive, encompassing urban, intercity, school, charter, paratransit and shuttle services. The report notes that the bus sector includes more than 55,000 vehicles, 85,000 employees and annual expenditures of over $5.38 billion.

The value of product engineering R&D expenditure in the bus and coach industry for Canada and the U.S. was estimated by IBI Group to total $121.3 million annually. The authors estimated that the level of R&D spent in Canada may be in the order of 25 percent or $30 million annually. In addition to these expenditures, manufacturers and suppliers spent a further $200 to $460 million over the past 10 years on new product development. The portion spent in Canada, given the number of Canadian manufacturers, was estimated to be in the order of $10 to $34 million annually

A successful implementation of the fuel cell bus deployment in British Columbia linked to the commercialization of the fuel cell drive system and bus platform in Canada will represent an integrated system solution that demonstrates the business value of fuel cell hybrid buses to the global marketplace. Perhaps even more importantly fuel cell bus engine development can accelerate the commercialization of light duty engine applications, providing large economic impacts to jurisdictions that capture early production of these products.

## AUTO INDUSTRY VALUE

### GLOBAL SIGNIFICANCE

The global significance to national competitiveness from the impact of a transformative technology like hydrogen fuel cells on the automotive industry is well described in "Fuel Cell Vehicles: Race to a New Automotive Future", Office of Technology Policy Technology Administration, U.S. Department of Commerce, January 2003.

In particular Chapter 2: Status and Prospects, provides an excellent discussion on the contribution of the automotive sector in developed economies. In the major automobile manufacturing countries, the automotive industry and industries dependent upon it account for five to ten percent of jobs. The automotive sector is a key driver of economic growth.

For example, more than 10% of the GDP of the United States in 2000 was generated by transportation related goods and services. It was responsible for 5% of private sector jobs. For every worker directly employed by an automaker, nearly seven indirect jobs are created. This is the manufacturing dynamic that the fuel cell industries can penetrate and participate in. This transition can only be accelerated by significant demonstrations like the bus purchase proposed.

In June 2002, the Canadian Vehicle Manufacturers Association submitted a "Discussion Paper on Canada's Contribution to Addressing Climate Change". It highlighted the economic significance of the automotive sector to the Canadian economy:

*"The automotive industry is one of the strategic cornerstones of the Canadian economy, with some 600,000 direct and indirect jobs across Canada. A recent University of Michigan report tags assembly plant job multiplier at 7.5 :1. Currently, the industry represents 15% of Canada's total manufacturing GDP, with automotive related exports accounting for about 22% of all of Canada's exports contributing to an annual net trade surplus of $20 billion dollars (cars/trucks, engines/parts). DaimlerChrysler, Ford and General Motors account for approximately 80% of vehicles produced in Canada."*

*"Canada's strategy must find ways to promote technology solutions and prepare now to capitalize on our leading edge research and development capabilities in the areas of fuel cells and other energy efficiency technologies."*

## Canada's Place

There will be large revenue and job impacts on the Canadian economy from commercialized fuel cell activity. The 2004 PwC Survey identified Canada, along with the USA, Japan and Germany, as a leading location for fuel cell related manufacturing and research and development activities.

Canadian companies are involved not only in fuel cell production and systems integration but also in many support services and functions. For example, Canada is the world leader in fuel cell test station development and marketing. As fuel cell production increases, so too will the demand for test stations. Market success for fuel cells will lead to after-market diagnostic testing, which will extend the product and service lines of these companies.

Hydrogen and fuel cells are one of British Columbia's most export-oriented technology clusters. As a cluster, it has already "paid back" to the economy through jobs, private sector investment, and federal and provincial tax revenues from company employees and shareholders. Revenues are projected to total $3 billion by 2010 and employment is projected to reach 10,000.

With increased demonstration and deployment close to home in real life applications, a skilled workforce will emerge along with other key infrastructure to support British Columbia's vision of a hydrogen economy by 2020.

The mere prospect of deploying 20 hydrogen fuel cell powered buses in daily revenue service has attracted the attention of authorities in London, California and Europe. They see the value and recognize this initiative as significant. Eyes are turned to Canada and nascent markets await the outcome.

## The Economic Impacts of Fuel Cell Commercialization

Since 2002 PwC has produced a series of reports on the economic development opportunity hydrogen fuel cells presents for Canada and potential economic impacts on the country from a commercializing industry.

The Canadian Fuel Cell Commercialization Roadmap (2003) identified critical factors for the industry to bring technologies to market and provide strategic planning tools for industry, academia, and governments. For governments, the Roadmap provided a strategic direction for industrial development activities.

The Roadmap identified four key steps to be taken for the Canadian industry to realize the major potential economic and environmental benefits of fuel cells, and to maintain Canada's leadership position in this emerging sector. Government was seen to have an important role in all of these steps.

### Step One: Stimulating early market demand

Recognising that higher production costs pose a prohibitive barrier to potential purchasers, the Roadmap advocated governments provide early demand to stimulate increased production volumes and lower costs.

**STEP TWO:** IMPROVING PRODUCT QUALITY WHILE REDUCING COSTS
There is significant need for continuing government and industry investment in fundamental and applied research and development in the fuel cell and hydrogen sectors.

**STEP THREE:** FINANCING
The fuel cell industry faces the challenge of increasing the scale and scope of operations, and gaining access to scarce private capital needed to support such growth, while still in the pre-revenue stage.

**STEP FOUR:** CREATING A SUPPORT INFRASTRUCTURE
Support infrastructure is necessary to allow the safe introduction of fuel cell applications, to promote interconnectivity and to develop a fueling infrastructure. Hurdles exist in obtaining skilled resources, developing fueling infrastructure, and developing codes and standards.

In "Fuel Cells, the Opportunity for Canada" (2002)[47], a number of scenarios were used to discuss the economic benefits to Canada of securing a share of fuel cell production.The scenarios demonstrated that securing a share of production, as well as growing R&D, is critical to the success of the Canadian fuel cell industry. Only one scenario ensures that the Canadian fuel cell industry can remain competitive and growing in the long term. That scenario described companies that were involved in both R&D and early production.

Successful market entry and pre-commercial production of fuel cell bus engines, based on the integration of a light duty stack in a hybrid heavy duty application, will drive commercialization benefits for the technology in both modes. The bus engine can accelerate the market entry of the car engine.

In 2002 PwC estimated that an early market production fuel cell engine plant would directly employ around 6,600 people.

In addition to the direct economic benefits of the fuel cell industry, indirect and induced economic benefits are generated:

- indirect economic activity occurs through the spending of fuel cell companies on goods and services provided by suppliers.

- fuel cell company employees generate induced economic activity by spending their income on personal goods and services throughout the economy.

As PwC noted, little analysis has been done on the economic impacts of the fuel cell industry. The most comprehensive study in Canada to date was undertaken in 1996 for the Government of British Columbia, using Ballard Power Systems as a model. The employment multipliers from this study (which were developed using the provincial government's British Columbia Input Output Model), were factored up by PwC to provide Canada-wide impacts. PwC estimated that each direct job in fuel cell production supports approximately 0.8 indirect jobs and 0.7 induced jobs, for a total of 1.5 indirect and induced jobs for every direct job. This is an employment multiplier of 2.5.

PwC applied the economic multiplier of 2.5 to yield a total of about 33,000 direct, indirect and induced jobs from an early market production plant employing 6,600 people.

In the 2004 Canadian survey PwC reported that the Canadian hydrogen and fuel cell industry as a whole employed 2,430 people. Applying an economic multiplier of 2.5 to this industry figure indicates that a total of about 7,436 direct, indirect and induced jobs were based on the sector in 2003 (the latest figures available) [48].

Salaries of those directly employed in the fuel cell sector in 2003 were estimated at $146 million (approximately $60,000 per person)

Based on these multipliers and the PwC commercialization scenarios it is possible (by adding standard manufacturing and service industry multipliers from Statistics Canada) to estimate the relevant impacts on the Canadian economy resulting from each job in a fuel cell sector moving to commercialization.

The resultant impacts on the Canadian economy from an early production fuel cell engine plant employing 6,600 people are:

| | |
|---|---|
| Wages: | $800 million |
| GDP: | $1.15 billion |
| Output: | $2.5 billion |

### Opportunities for Canadian Companies Across the Value Chain

According to PwC's 2004 survey, 70% of the demonstration projects involving Canada's fuel cell actors are taking place outside of Canada. As PwC notes, Canada's fuel cell industry participates in the international marketplace across the value chain as:

- fuel Cell stack manufacturers and system integrators
- producers of fuel cell stacks sold to system integrators
- producers of materials and components sold to fuel cell producers
- producers of applications using fuel cells
- sellers of proprietary knowledge to fuel cell producers in other countries
- developers of fuel and fueling infrastructure, parts and systems
- providers of service and support technologies

Canada's maturing fuel cell sector can leverage the hybrid bus project to advance the country's leading position in the international hydrogen and fuel cell marketplace.

## Leadership: The Challenge for Canada

Canada is a global leader in the hydrogen and fuel cell sector, as witnessed by the participation of its industry in demonstration and deployment programs worldwide, notably in transportation applications, including fuel cell bus demonstrations and supporting hydrogen fueling infrastructures. As described earlier however, competing jurisdictions have accelerated their investments in the sector through highly targeted strategies, funding programs and enabling policies. Recognising the economic development, environmental, health and energy efficiency benefits of fuel cells, the developed economies of North America, Europe and Japan, alongside the newly developing economies of Asia, are now leading the way as early adopters of fuel cells across many applications, including transportation applications and fuel cell buses.

Government in Canada must keep pace with this competition. Failure to do so will mean that Canada not only foregoes the commercial opportunities from early production of automotive fuel cells and fuel cell buses described above. Inaction will threaten the continued viability of the earliest, and arguably most developed, hydrogen and fuel cell cluster in the world.

# Chapter 5: Roadworks: Analysis of Industry Response

BC Transit needed to determine if industry was ready and able to supply the fleet and fueling infrastructure in a timeframe and to a specification that would enable deployment of 20 fuel cell hybrid buses by 2009 in Whistler. To that end, it convened a one day symposium of 70 decision makers and technical experts from the bus manufacturing, fuel cell system, fuel (hydrogen) supply and fueling infrastructure industries. At that meeting, BC Transit presented to them its vision, concept of operations and performance requirements as well as the contextual background for the proposed purchase. All participants left with a five page Request for Information specifying operational and technical needs with a request that they respond no later than August 31, 2005 with comments and suggestions as to their ability and interest to comply. (materials provided can be found in Annexes C and D)

Nine responses were received from a variety of industry consortia. Five responses addressed bus proposals and four addressed fuel supply and fueling infrastructure. All responses from industry confirmed that the project as described at the Whistler meeting was feasible within the time frame described. On the bus manufacturing portion of the project there were a few variations in terms of conditions under which the object could be met. The fueling solutions addressed in the responses were also achievable with several options suggested for hydrogen fuel supply.

## Bus Procurement

Buses will be procured through existing bus manufacturers on a competitive basis. The bus manufacturer will be the prime contractor for the supply of the fuel cell hybrid bus fleet, after sales support and the point of contact for all warranty issues. The fuel cell system and hybrid drive system will be subcontracted to other suppliers by the prime contractor. Warranties for the fuel cell components and hybrid drive components will be provided by the respective manufacturers and flowed through the bus manufacturer. The bus manufacturer will be responsible for providing, as part of the contract, all training required by BC Transit and Whistler Transit personnel for the operation, maintenance and fueling of the proposed fleet. Spare parts inventories will be supported by the prime contractor. Second line repair will be accommodated by the fuel cell and hybrid drive system providers as necessary.

It is apparent from industry responses that the first bus could be delivered to BC Transit in Victoria in March, 2008 on the condition that confirmation of contract and an order is placed no later than June, 2006. All buses could be phased through BC Transit in Victoria but delivery schedules can only be confirmed at the time of contract award. The number of phases is flexible depending on the requirements of BC Transit. No more than five buses will be operational in revenue service in Victoria at any given time prior to deployment to Whistler. All buses can be delivered to Whistler, by the latest, in the summer of 2009. The proposed delivery schedules will allow the first buses to experience winter conditions in Whistler during the winter of 2008/09. All buses will have experienced winter operating conditions prior to the 2010 Games in February, 2010.

In general, the following bus performance specifications can be met by industry:

- seated passenger capacity of 39 with a maximum capacity of no fewer than 60
- low floor design partial or complete to facilitate access
- able to meet the grades encountered on Whistler transit routes
- range of approximately 500 km
- fuel cell and advanced battery storage (NiMh battery systems) to provide comparable power output of current diesel powered buses
- on board hydrogen storage of 350 bar or 5,000 psi
- capable of operating in temperatures as low as -20˚C

Bus designs will be compliant with technical specifications that deal directly with hydrogen and fuel cell vehicle safety such as SAE J2578, NFPA52, and NGV2.

All manufacturers were provided route profile data to assist them in analyzing the feasibility of the proposed project. Analysis of this data confirmed that the power and range required for Whistler operating demands could be achieved with on board storage of no more than 50 kg of hydrogen gas. During the engineering design stage this fuel load could be reduced somewhat.

### Facilities Adaptation

Current facilities at both the BC Transit Langford Depot and the Whistler Transit Depot are not built to prevailing hydrogen design standards. While the Langford Depot facilities were originally designed to meet CNG standards, some of those standards have been compromised and will have to be reassessed.

All facilities accommodating hydrogen buses whether it is for storage, maintenance, or fueling must meet, as a minimum, the Canadian model safety codes that form the basis of regulations that affect urban transit facilities which are:

- the Canadian Electrical Code (CSA Standard C22.10)
- the National Gas Codes (CSA Standards B149.1 and B149.2)
- the National Building Code of Canada
- the National Fire Code of Canada
- the National Plumbing Code of Canada
- the Boiler, Pressure Vessel and Pressure Piping Code (CSA Standard B51)

In addition to the facilities design requirements, equipment in the maintenance garages will need to be assessed to ensure it is suitable for the maintenance requirements for fuel cell hybrid buses:

- fuel cell hybrid buses will have a curb weight of about 16 tonnes. Hoists used in maintenance bays must have the capacity to lift this weight with a sufficient margin of safety
- as the fuel cell hybrid bus will be about 3.7 metres tall, it will be essential to ensure there are no overhead obstructions once hoists are raised to the optimum heights to allow servicing below the bus, normally between 1.5 to 2.0 metres off the ground
- with hydrogen being lighter than air, service pits used for inspection of standard diesel or CNG buses can be used for fuel cell buses
- maintenance bays where roof top work is done should be equipped with fall protection equipment and have access to portable gantries to allow maintenance personnel to work safely
- overhead lifting capability should also be provided in the way of a track-mounted hoist, or hoists, that can be shared among bays
- bus wash facilities that do not have adjustable roof wash roller brushes will have to be modified to accommodate the increased height of fuel cell buses

### Fueling Load and Infrastructure

Industry responses confirm that no more than 50 kg of on-board hydrogen storage, at 350 bar or 5,000 psi, will be required to meet the operating requirements in Whistler. As 20% of the fleet will be operational spare buses, with the occasional simultaneous use of all buses in the fleet, it is anticipated the average daily requirement for hydrogen fuel should be in the order of 800 kg/day. Precise on-board storage and fueling requirements will only be determined during the detailed design stage of the buses. For the Victoria phase of the proposed procurement a fueling requirement of about 150 kg/day will be sufficient.

All potential fuel suppliers have confirmed their ability to provide liquid or gaseous hydrogen supply or to generate hydrogen on site to the required purity. Fueling infrastructure costs will include all the necessary support equipment such as electrolyzers, storage units, compressors and dispensers as required, and can be financed from down-stream billing on an agreed upon “nozzle price” per unit of hydrogen.

Spatial requirements for fueling infrastructure to accommodate both the foot-print of generation and storage facilities and fueling bays is estimated to be about 800 $m^2$ , not including circulation space. Actual circulation space will have to be determined during site design based on the configuration and size of land available. There will not likely be any limitations at the Langford depot in Victoria. The availability of space in Whistler, however, may be a challenge and a risk that will need to be dealt with in the planning leading up to the 2010 Games.

### Planning and Operations Requirements

Industry has confirmed that it is able to provide fuel cell hybrid buses that can meet all the performance specifications that will be required to effectively deliver service in Whistler. This confirms that Whistler Transit should be able to provide current levels of service with little or no planning and operating adjustments. In other words, fuel cell technology will be transparent to the planning function and to the service provided to customers.

The introduction of fuel cell technology will, however, have an impact on bus maintenance and facility maintenance operations. Maintenance operations will require the acquisition of some specialty tooling, clothing or equipment to comply with the predicted maintenance requirements. These tools will be over and above those on hand for the maintenance of standard diesel buses.

### Staffing and Training

The impact on operations and maintenance staffing should be minimal. No change in the ratio of bus drivers or service persons to buses is anticipated. Industry confirms that the skills of current diesel mechanics are easily adaptable to the skills required to maintain fuel cell hybrid buses after the required training. Training will be provided by the suppliers of the buses and the fueling stations.

The amount of training that will be required should be limited to:

- no more than two days for operators and service personnel
- five days for maintenance personnel
- one day for facilities building maintenance personnel unless this function is performed by qualified contracted facilities maintenance service providers

Operator and service person training will include vehicle operation, system start-up, fuel cell start-up, pre-trip inspection, general driving instructions and controls, vehicle driving diagnostics, fault codes and emergency shut-down procedures. In addition, service personnel will be trained on the safe operation of the fueling station. Fuel suppliers will be responsible for the maintenance of the fueling infrastructure.

Maintenance staff training will focus on procedures unique to fuel cell and hybrid systems as well as on high pressure and high voltage systems, trouble-shooting, and unique software. All maintenance personnel, including those involved with stores and parts-handling, will be required to have training in the handling of sensitive parts and equipment related to fuel cell system maintenance.

Facilities building maintenance trades will require skills upgrading to include the testing and replacement of hydrogen sensors and fire detection and suppression systems in the buildings.

All personnel will require occupational health and safety training unique to hydrogen.

Suppliers will also provide training to first responders in the case of a vehicle accident or accident or fire within the operating facilities. This training will include response actions related to high voltage and hydrogen safety.

## Regulatory Requirements

### Authorities

There are several authorities that may have jurisdiction over the operation of fleets in a hydrogen environment. For maintenance and garage facilities and indoor and outdoor fueling facilities, the Canadian model safety codes, identified earlier, apply. The Canadian model safety codes define an "Authority Having Jurisdiction" as the governmental body responsible for enforcement of any part of a regulated code or standard, or an agency designated by that body to exercise such a function. The Canadian Authorities Having Jurisdiction are primarily the provincial and territorial governments, who in turn assign the responsibilities for development of regulations and enforcement to their related departments. These regulations are then utilized by local officials, such as building inspectors or fire chiefs, who may be employed by a provincial or federal government department, a city, a municipality or a planning district. The person delegated with local responsibility for the regulatory decision varies from location to location.

### Approvals

For the proposed project the municipal officials responsible for enforcing the regulations established by higher authorities will have the approving authority as necessary.
In terms of fire safety precautions, the local fire marshal will approve the fire safety design parameters.

### Environmental Assessment

It is not clear whether an environmental assessment will be required for hydrogen fueling stations. While normal gasoline and diesel fueling stations do require environmental assessments, the extent of such an assessment for hydrogen fueling stations needs further investigation. Other than safety distances between contiguous properties to accommodate fire and explosion, which are addressed during the facility design stage, all other spills or gas releases from an hydrogen fueling facility are environment friendly. It is also possible that agencies funding this proposed project may have unique assessment requirements which will have to be investigated.

If a new operating facility is constructed for the Whistler transit operations, the normal environmental assessment for any new construction will need to be carried out.

### Budget Requirements

Based on the responses from industry, BC Transit estimates the funding requirement over seven years for the proposed project is $89 million, broken down as follows:

**Capital**

The capital funding component will include:

| | |
|---|---|
| • Bus procurement | $50 m |
| • Facilities upgrades | $ 2 m |
| • Power train conversion | $ 4 m |
| • Project support costs | $ 2 m |
| | $58 m |

**Operating**

The operating funding component includes operating and fuel costs of $31 million.

### Financing

The funding for the implementation of this project will be shared between municipal, provincial and federal levels of government. The BC Transit share of the total budget requirement of $89 million will be the equivalent funding that would normally be required for procuring and operating a fleet of diesel electric hybrid buses. This contribution will total $31.4 million. Incremental funding of $57.6 million is being sought from other levels of government.

### Timetable and Scheduling

Time is of the essence in implementing this project if the fuel cell fleet is to be fully operational and reliable for the 2010 Games. To achieve this objective the following schedule must be met:

- initiate project management capability – 1 Dec 2005
- issue Request for Expression of Interest and Statement of Qualifications – 1 Dec 2005
- receive responses to REI – 28 Feb 2006
- funding Confirmation – 31 Mar 2006
- issue formal Request for Proposals for each of fleet and fueling capability – 31 Mar 2006
- initiate design of Victoria and Whistler facility upgrades – spring 2006
- receive responses to RFP – 31 May 2006
- evaluate proposals and award contracts – no later than 30 Jun 2006
- complete Whistler facility upgrades and construction – fall 2008
- complete Victoria facility upgrade – spring 2008
- install Victoria fuel facility – spring 2008
- first buses delivered to Victoria – summer 2008
- install Whistler fuel facility – spring 2009
- deploy and commissioning buses in Whistler – winter 2008/09

It is imperative funding commitments be confirmed as soon as possible and that spending authority be in place no later than 31 March, 2006. A delay beyond this date will compromise the ability to have the proposed fuel cell hybrid fleet fully operating in Whistler in time for the 2010 Games.

# Chapter 6:

## Conclusions and recommendations

*"Consultations have also begun with the provinces and territories to identify strategic new technologies (such as fuel cell buses) and infrastructure projects for cost sharing through the Partnership Fund"*

**Hon. Stephane Dion,** Minister of the Environment at the Vancouver Board of Trade, Sept 19, 2005

This feasibility study was launched to answer a limited number of critical questions. Believing the time was right to move from technical trials of hydrogen fuel cell-powered buses, BC Transit wanted to know:

- if a fleet of 20 fuel cell hybrid buses could be manufactured, delivered and revenue service by 2009 as an integral part of the Whistler transit service
- the benefits and opportunities of such a purchase
- the administrative and logistical challenges
- the premium cost over and above equivalent number of diesel electric hybrid buses and
- how to manage the risks involved.

The research and consultation conducted in the course of this study concludes, first and foremost, that a purchase proposed by BC Transit at this time in British Columbia represents an unprecedented opportunity to accelerate the commercial introduction of zero emission transportation in transit operations around the world and to secure the lead of Canadian innovation in this effort.

Specific conclusions from this study effort are:

- industry confirms that the BC Transit vision can be achieved within the timeframe 2006-2010 and is prepared to participate subject to financing being in place

- major risks inherent in this purchase are operational rather than technological in nature

- engineering and operational issues have been identified and a risk management plan designed

- the global transit bus market for this technology is large and lucrative

- Whistler needs innovative transport solutions to sustain airshed quality

- deploying and managing hydrogen fuel cell transit fleets have significant environmental and social benefit and economic potential for British Columbia and Canada

- a purchase of this size supports and sustains governments' commitment to and investment in the Hydrogen Highway™

- this purchase highlights the value of BC's power technologies cluster
- 2010 Games provide a singular opportunity to showcase to the world hydrogen fuel cell applications in commercial public transit fleets
- this purchase delivers dramatically on the promise of a "Sustainable Games" in 2010
- Canadian companies currently lead in commercializing fuel cells for bus applications but are at risk of losing that world leadership as other nations and jurisdictions more aggressively finance their commitment to the hydrogen transport future
- there is a small window of opportunity for Canada to outpace competing jurisdictions in leading the way to commercial application of this technology
- the incremental funding for this fleet purchase amounts to $57.6 million
- the decision to move on this purchase can only be made by government agencies as a matter of social and economic policy
- if funds are not committed by March 31, 2006, the purchase cannot be made in time to take advantage of the 2010 Games showcase opportunity

If governments and industry in Canada desire to maintain and enhance their international reputation as pioneers in clean air transportation policy and technology and showcase that innovative spirit and its results to the world, the time to act is now.

Specific recommendations are that:

1. governments recognize the unique opportunity and timing this proposed purchase offers
2. governments and industry share the vision by committing the necessary resources (time, effort and finances) to make it happen
3. BC Transit engage in activities contained in the implementation plan and schedule to ensure no time is lost
4. a funding commitment be made and financing in place no later than March 31, 2006

# Annex A

## BC Transit Implementation Plan
## Fuel Cell Hybrid Bus Fleet Deployment

### Situation

Canadian, American, Japanese and European suppliers have provided bus platforms to carry fuel cell drive technologies for international demonstration projects. The development of the fuel cell drive system itself in bus applications however has been led by Canada. Canadian companies have provided more than sixty per cent of bus drive systems delivered worldwide to date. Around one hundred fuel cell buses have been produced globally, with power systems for at least sixty of them supplied from Canada. These demonstration projects continue to provide valuable empirical information on the operation, safety, and reliability of the related fuel cell and hydrogen technologies. However, the market opportunities and the value-added associated with providing a complete fleet deployment and operational solution can be more significant than all the individual technology niche markets combined.

Public transit systems in Canada provide service to over 2.37 billion riders per year of which over 68% are carried by bus systems on approximately 2,600 fixed routes. The combined bus fleets of over 12,000 vehicles travel over 815 million kilometers in over 35 million service hours and consume about 380 million litres of diesel fuel per year. Over 7,000 of the buses currently operating will be scheduled for replacement within the next ten years.

Urban transit systems are the best candidate for the immediate introduction of fuel cell propulsion systems. The reasons behind this conclusion include the following:

- transit buses are centrally refuelled and maintained
- transit buses are typically operated on fixed routes, with urban, stop-and-go duty cycles
- transit bus architecture is more forgiving toward the size and weight requirements in new technologies
- capital purchases of transit buses and supporting infrastructure can leverage government leadership and funding

Fuel cell hybrid buses are at an advantage in terms of deploying the technology into transit operations for the following reasons:

- increased efficiency with advanced energy storage devices
- brake energy recovery
- ability to use light duty vehicle rated fuel cell systems
- reduced hydrogen consumption
- independent operation of the individual power systems

## Objective

To procure and deploy twenty (20) fuel cell hybrid buses into regularly scheduled revenue service in the Resort Municipality of Whistler in time for the 2010 Games and to evaluate sustained, long-term life cycle demands imposed by these buses on operations, maintenance and fueling activities.

## Implementation Plan

Procurement of the proposed fuel cell hybrid bus fleet will be phased, allowing for the commissioning of the fleet in Victoria where there is a depth of technical expertise and start-up issues can be dealt with expeditiously prior to deployment to Whistler. In Whistler the fleet will be used in regular revenue service. Support infrastructure for maintenance and fueling will be placed in Whistler for the entire 20 bus fleet.

The fleet will be powered by the latest edition of pre-commercial fuel cell engine technology. The initial fuel cell engine stacks will be operated for 4,000 to 5,000 hours. The design of the buses will permit the installation of commercial fuel cell engine technology that industry expects to be readily available in 2010. Commercial fuel cell technology is expected to attain a useful life of from 15,000 to 20,000 hours, approximately the life of contemporary heavy duty diesel engines. Should the fuel cell technology not meet expectations or operational requirements, provision is made in the project funding to convert the power train to low emission technologies, such as hybrid hydrogen internal combustion engines.

The project from definition, through procurement, commissioning and deployment will be managed by BC Transit on behalf of the funding partners. Participants in the project will be:

- federal, provincial, and municipal governments
- the bus manufacturer and its suppliers
- the fuel supplier
- BC Transit
- the Whistler transit service contractor

### Roles and Responsibilities

#### Federal, Provincial and Municipal Governments and Industry

Federal, provincial and municipal governments and industry will support this project principally through the provision of funding, leadership, and development of sustainable policies. Additionally these levels of government through policy development will facilitate the advance and commercialization of hydrogen technologies.

#### BC Transit

BC Transit, the managing agency for the fleet implementation, is responsible for chairing a project steering committee to give direction to the project and for establishing a project management team to be in place prior to the initiation of the procurement process to carry out the following:

- managing the procurement of the fuel cell bus fleet including the RFP process, proposal evaluation, contract negotiation, contract administration, budget management, manufacturing oversight, and fleet commissioning
- preparation of facilities, including the upgrading of the Langford Transit Centre in Victoria to hydrogen standards and the construction of hydrogen ready maintenance and operating facilities in Whistler
- identifying and procuring a site or sites in Whistler for the required hydrogen fueling station and other facilities that may be required
- training of BC Transit personnel required to implement the project
- adapting existing maintenance procedures and processes to incorporate fuel cell related maintenance requirements
- managing the after sales service support and warranty issues related to operating the fleet
- preparing an emergency response plan for all facilities and for the fleet while it is in revenue service
- establishing fleet evaluation and reporting criteria for all stakeholders
- public relations and stakeholder communications to ensure the procurement is well advertised and understood to ensure on-going support and to assist industry in achieving its product objectives

**Bus Manufacturer**

The bus manufacturer will be selected through a competitive procurement process. The successful proponent will be responsible for:

- establishing a consortium of required technology providers including, the coach, the power train and integration specialists
- delivery to Victoria, starting in the summer of 2008, of 20 fully engineered fuel cell hybrid buses
- after-sales service support and spare parts including full manufacturers' flow through warranty on all components of the bus including the power train
- training of trainers, operators, maintenance and first responder personnel and the provision of full service and safety manuals
- identifying recommended tools and equipment required to maintain the buses

To provide for stack or power train replacement after the useful life of the initial fuel cell stacks, the design of the proposed buses must allow for conversion to an alternative zero emission technology if and when necessary.

### Fueling Contractor

The fueling contractor will be selected through a competitive procurement process. The successful proponent will be responsible for:

- providing  turnkey fueling stations
- completing an environmental assessment as necessary
- capturing the total capital cost for fueling infrastructure through the nozzle price of hydrogen
- maintenance of all fueling infrastructure and responding to emergency situations
- provision of a two day reserve at the Whistler site
- provision of a fueling capability to support the phasing of the fleet through the Victoria site

### Whistler Transit Contractor

The contractor providing transit service to the Resort Municipality of Whistler under contract to BC Transit is responsible for operating and maintaining the fuel cell bus fleet in regular revenue service.  To this end the contractor will:

- recruit and train the required number of operators to drive the buses
- recruit and train the maintenance personnel required to conduct running maintenance of the fleet.  The service provider will be assisted in this regard by both BC Transit and the bus manufacturer.
- carry out routine operating functions required to keep the fleet in service

## Operations and Management Plan

The fleet of fuel cell buses will be deployed in two phases. Initial delivery will be to BC Transit in Victoria where the buses will be commissioned and tested prior to being run in regular revenue service for a few months. It is anticipated the buses will be delivered over a period of up to twelve months starting in the summer of 2008. This phase will allow BC Transit employees and technical staff to become familiar with the technology to properly support the fleet once it is deployed to Whistler. Maintenance processes can be tested and modified as necessary during this phase. Data collection processes will be established and statistical reports prepared on the performance of the fuel cell buses.

The second phase of the deployment will be to Whistler in advance of the 2010 Games. The advanced deployment of a few buses to Whistler is planned in the winter of 2008/09 to permit the training of all Whistler Transit employees to be conducted and to adjust maintenance and operating planning and processes before the start of the Games.

All buses should be deployed to Whistler by the summer of 2009. The buses will be operated on all routes in regular revenue service.

A project management team will be established by BC Transit to undertake all project management processes. This team will provide the following functions:

- project management, including project reporting as required
- procurement
- contract administration
- budget management
- implementation of codes and standards
- facilities upgrade and construction
- public relations and stakeholder communications

The team will comprise full-time and part time employees, some of whom will be seconded as necessary from BC Transit to the project. It is expected the first members of the project management team will be engaged as early as December 2005 to initiate the preliminary procurement processes such as a Request for Expressions of Interest to Industry and the development of the formal Request for Proposals document.

A functional relationship diagram of the management team is at Appendix A.

## Technical Requirements

### Facilities

Any facility to be used by hydrogen fuelled vehicles must comply with and be designed to current applicable codes. The structures should consider:

- hydrogen gas leak detection and special positive ventilation that initiates automatically when gas is detected
- fire detection and suppression systems
- discharge fans must be rated for operation in Class 1, Zone 1 environment, with preset alarms that double the speed at 10% lower explosion limit (LEL) and shut off facility power at 20% LEL
- explosion venting capability
- explosion-proof electric systems
- explosion-proof lighting
- ignition-free space heating equipment

The will be built of fire resistant materials that are also resistant to hydrogen embrittlement. Space requirements for the required facilities will be in accordance with the current norms for transit operations.

### Buses

The buses proposed for this procurement must meet the following specifications:

- a seating capacity of at least 39
- a maximum passenger capacity of no less than 60
- fully accessible low floor configuration
- minimum range of 500 km
- on board hydrogen storage of 350 bar or 5,000 psi
- a reliability factor of 80%
- be able to be stored outside when not in use
- meet or exceed the specifications of current standard diesel buses
- be capable of operating in temperatures as low as -20˚C

### Fueling Station

The fueling station provided to support the fuel cell bus fleet must meet the following capabilities:

- producing up to 1,000 kg of hydrogen per day at the Whistler site at a purity required by the fuel cell supplier
- achieving a refueling rate of no more than ten minutes per bus
- delivering up to 150 kg of hydrogen per day at the Victoria Langford site
- have fire detection and suppression capability
- be of such a design to allow transit staff to dispense fuel with minimal training

## Timings

Time is of the essence in implementing this project if the fuel cell fleet is to be fully operational and reliable for the 2010 Games. To achieve this objective the following key milestones must be met:

- initiate project management capability – 1 Dec 2005
- issue Request for Expression of Interest and Statement of Qualifications – 1 Dec 2005
- receive responses to RFI – 28 Feb 2006
- funding Confirmation – 31 Mar 2006
- issue formal Request for Proposals for each of fleet and fueling capability – 31 Mar 2006
- initiate design of Victoria and Whistler facility upgrades – spring 2006
- receive responses to RFP – 31 May 2006
- evaluate proposals and award contracts – no later than 30 Jun 2006
- complete Whistler facility upgrades and construction – fall 2008
- complete Victoria facility upgrade – spring 2008
- install Victoria fuel facility – spring 2008
- first buses delivered to Victoria – summer 2008
- install Whistler fuel facility – fall 2008
- deployment and commissioning of buses in Whistler – winter 2008/09

An implementation schedule is shown at Appendix B. More detailed implementation schedules will be prepared once project funding is confirmed and contracts have been awarded for the procurement of the buses and fuel supply.

## Risks

A number of risks may have a significant impact on the ability to meet the challenging time line proposed above:

- a delay in the funding commitment beyond 31 March, 2006 may make the deployment of a fuel cell hybrid bus fleet to Whistler by the 2010 Games unachievable
- the securing of a suitable site in Whistler for the hydrogen fueling station that meets both operational requirements and affordability
- the complexity of the environmental assessment that may be required
- any delay in the design and manufacture of the bus fleet, which are on the critical path to meeting the objective, will result in the fleet not being available in time for the 2010 Games
- the possibility that the technology will not be mature enough in time to withstand the rigours of extensive regular revenue service

## Funding Plan

The total project cost over the seven year period of the project for the deployment of a fleet of 20 fuel cell hybrid buses is approximately $89 million. BC Transit will contribute the cost equivalent of purchasing and operating 20 diesel-electric buses, estimated at $31.4 million. Incremental funding of $57.6 million is required.

### Capital Requirements

Capital funding required for the purchase of the bus fleet, the provision of facilities, future conversion of the power train, and project support costs is $58 million.

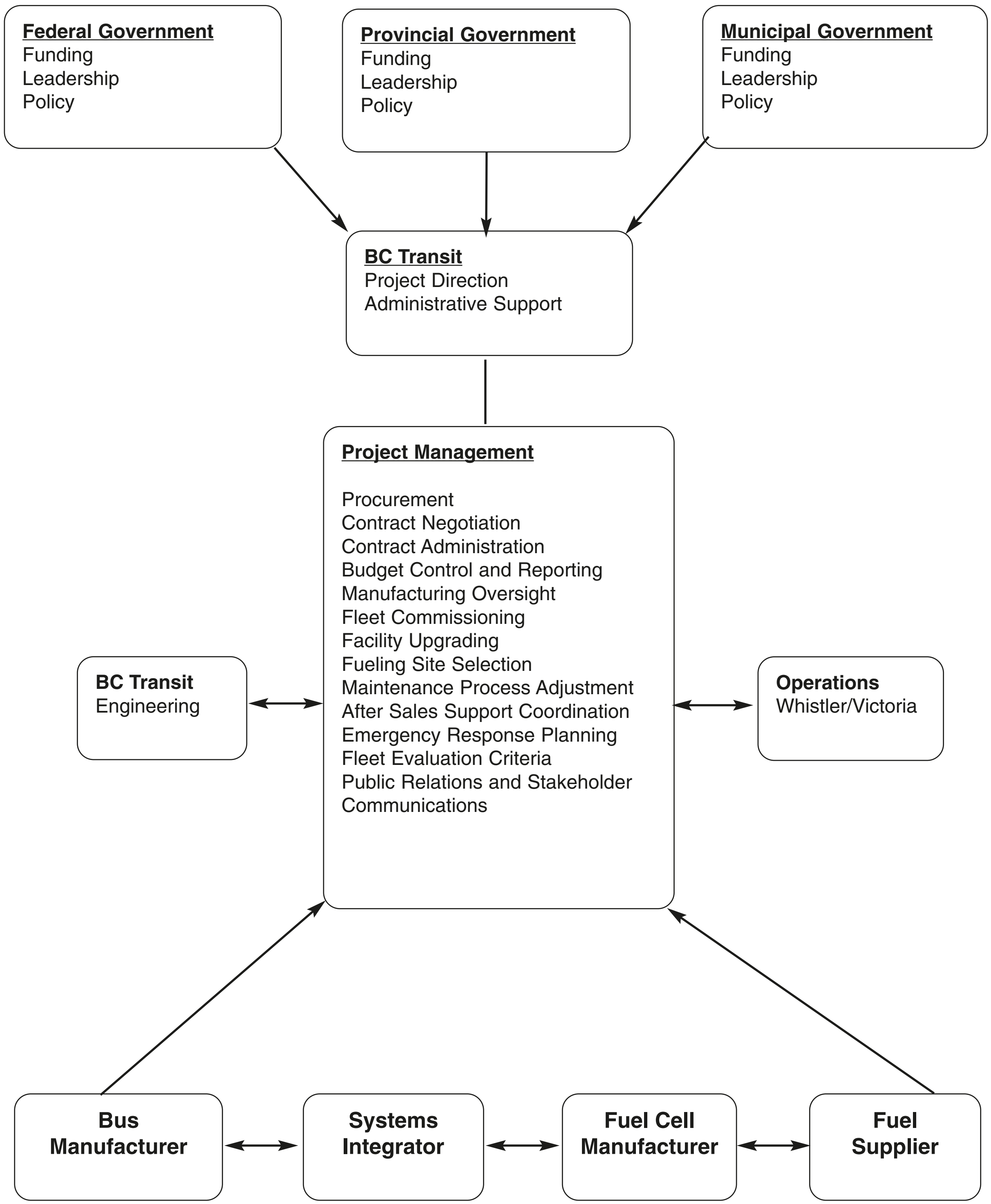
### Operating Fund Requirements

Operating fund requirements for the fuel, incremental maintenance, project management, support resources and an operating contingency is $31 million.

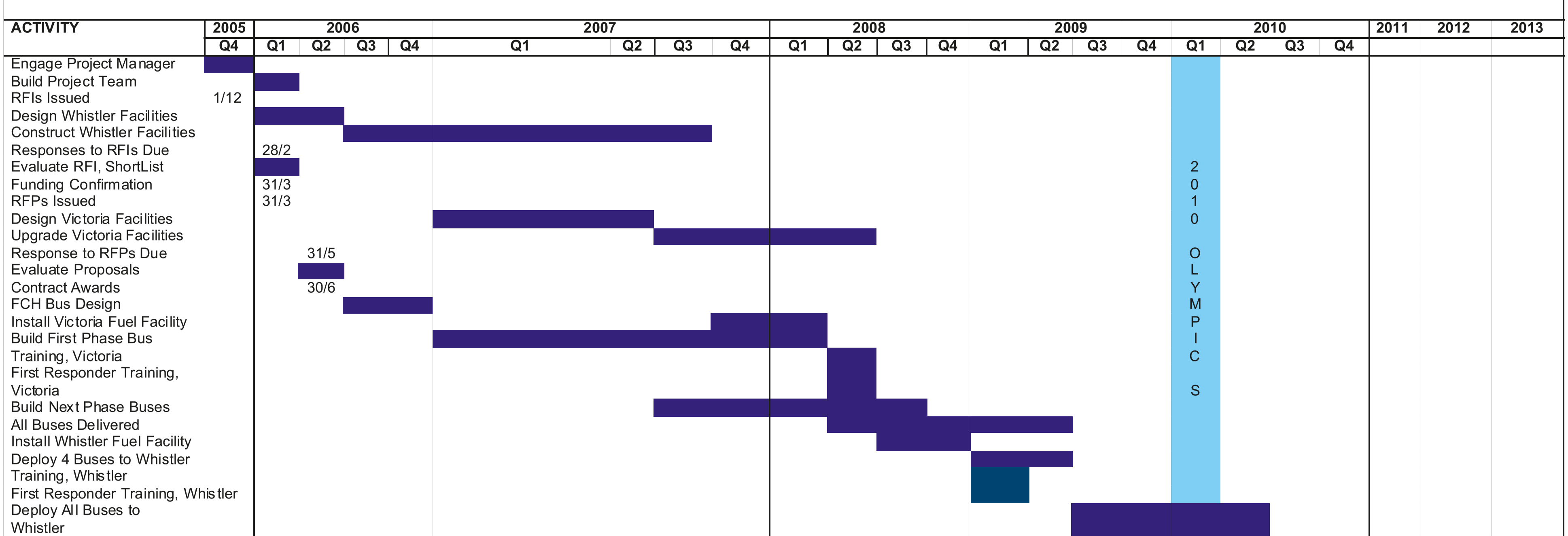
### Funding Contribution

The funding for the implementation of this project will be shared between municipal, provincial and federal levels of government. The municipal and provincial share of the total budget requirement of $89 million will be the equivalent funding that would normally be required for procuring and operating a fleet of diesel electric buses. This contribution is estimated at $31.4 million. Incremental funding of $57.6 million will be provided from senior governments. Industry contribution will be negotiated during the procurement process.

# Appendix A: Project Functional Relationships



# Appendix B: Implementation Schedule and Estimated Cash Flow




| | 2005 Q4 | 2006 Q1 | 2006 Q2 | 2006 Q3 | 2006 Q4 | 2007 Q1 | 2007 Q2 | 2007 Q3 | 2007 Q4 | 2008 Q1 | 2008 Q2 | 2008 Q3 | 2008 Q4 | 2009 Q1 | 2009 Q2 | 2009 Q3 | 2009 Q4 | 2010 Q1 | 2010 Q2 | 2010 Q3 | 2010 Q4 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cash Flows(2005$ x 1,000):** | | | | | | | | | | | | | | | | | | | | | | | | |
| Capital | 20 | 91 | 191 | 791 | 791 | 966 | 866 | 10291 | 10341 | 10411 | 9381 | 8964 | 64 | 94 | 64 | 74 | 54 | 54 | 54 | 54 | 54 | 110 | 110 | 4110 |
| Operating | | | | | | | | | | | 290 | 350 | 350 | 650 | 650 | 1595 | 1595 | 1595 | 1595 | 1595 | 1595 | 6380 | 6380 | 6380 |
| **Calendar YearCash Flows:** | **20** | **91** | **191** | **791** | **791** | **966** | **866** | **10291** | **10341** | **10411** | **9671** | **9314** | **414** | **744** | **714** | **1669** | **1649** | **1649** | **1649** | **1649** | **1649** | **6490** | **6490** | **10490** |
| **Total Funds:** | | | | | | | | | | | | | | | | | | | | | | | | **89000** |

| **Fiscal Year Cash Flows:** | FY 05/06 | FY 06/07 | FY 07/08 | FY 08/09 | FY 09/10 | FY 10/11 | FY11/12 | FY12/13 |
|---|---|---|---|---|---|---|---|---|
| | **111** | **2739** | **31909** | **20143** | **5681** | **6570** | **6490** | **15358** |

**N.B. Detailed dates will be confirmed once contracts awarded**

# Annex B: Methodology

## Purposes

1. To determine if the bus manufacture, fuel cell system and fuel providing industries are ready and able to supply the fleet and fueling infrastructure in a timeframe and to a specification that would enable deployment of 20 fuel cell hybrid buses by 2009 in Victoria and Whistler

2. To determine what financing premium would be required to make this happen and

3. To determine what social benefits and economic opportunities this strategic purchase would hold for Canada and British Columbia into the future

## Activities

- framed the feasibility question and study process
- assembled the study project team:
    - Mr. Ron Harmer, Vice President Technical Services, BC Transit – Project Manager
    - Mr. Chris Lythgo, President, Seajay Consulting – Technical Advisor
    - Dr. Walter Merida, University of British Columbia – Technical Advisor
    - Mr. Stephen Brydon, BC Ministry of Energy – Policy Advisor
    - Mr. Allan Collier, ATC Management Services – Project Coordinator
    - Mr. Bob Irwin, Irwin Transportation Services Inc – President
- fuel Cells Canada – Symposium Logistics
- prepared a Concept of Operations and Request for Information
- quantified health, environmental and social benefits of deploying this fleet in the target area
- quantified damage and costs of environmental degradation caused by GHG emissions from diesel transport in general in BC and transit buses in particular
- convened on June 17, 2005 a one day symposium of decision makers and technical experts from the bus manufacturing, fuel cell system, fuel (hydrogen) supply and fueling infrastructure industries
- presented to them the BC Transit vision, concept of operations and performance requirements as well as the contextual background for the proposed purchase which included federal and provincial support to the hydrogen economy vision, Whistler's commitment to environmental remediation and stewardship and the 2010 Games
- distributed the five page Request for Information specifying operational, technical and systemic needs with a request that they respond by August 31, 2005 with comments and suggestions as to their interest and ability to comply
- Tabulated responses to determine the range of costs and options
- Developed an Implementation Plan and Schedule that reflected realities identified by industry

# Annex C: Concept of Operations

**Power Point Presentation Transcript**
**Hydrogen & Fuel Cell Vehicles**

Slide 1:
**About BC Transit**
- BC Transit, a provincial Crown Corporation responsible for providing transit service in the province of British Columbia outside of the metropolitan Vancouver area.
- Mandate, includes planning, funding, marketing, constructing and operating, either directly or indirectly, the Victoria Regional Transit System and local transit systems in 50 communities throughout the province.
- Owns +500 conventional buses, 210 paratransit style vehicles
- Operates in 50 different communities in BC
- Over 39 Million trips in 2004
- Will be purchasing over 200 40' buses (>$100M) in next 5 years
- ~$150M/yr operating costs shared 40/60 (prov/local municipal government)

Slide 2:
**Why is transit a target for early adaptation of Fuel Cell technology around the world?**
- Transit is largely an entity of an urban city
- Leadership is usually politically motivated
- Generally environmentally friendly
- Publicly subsidized around the world
- Large consumer of fossil fuels
- Professionally managed with excellent trades skills
- Centrally operated
- Traditionally early adopters

Slide 3:
**Public Transit in Canada**
- Transit passenger service, that includes both bus and rail, is provided to over 2.37billion riders per year
- 68.5% carried by bus systems on approximately 2,600 fixed routes in Canada
- Combined fleets in Canada travel over 815 million kilometres in over 35 million hours
- 12,000 buses of all types across the country
- Average age of active transit buses: 10.81 yrs
- About 7,000 buses operating in Canada over 15 years in age
- Approximately 96% of the Canadian transit fleet composed of standard 40-foot buses
- 380 Million litres of diesel /year
- Governments currently subsidize transit operations for 38% of the total costs

Slide 4:
**The Opportunity**
- To showcase state-of –the-art technologies for 2010 Olympic and ParalympicWinter Games Vancouver –Whistler
- BC Transit as a provincial transit agency taking the lead role in operating these technologies
- At the same time significantly enhance economic opportunities

Slide 5:
**Hybrid Fuel Cell Bus Purchase**
- BC Transit will spend over $100M in next 5 years on vehicle purchases and would like a choice in technologies
- Significantly reduce GHG's
- to engage Canadian public in Hydrogen technologies

Slide 6:
**Current Status**
- Feasibility study funded and underway
- Business case required to integrate a large scale, fleet of fuel cell hybrid buses into regular transit operations
- Need input from industry to complete both
- Need inputto designproject management strategy

Slide 7:
**Objectives**
- Move from 1-3 bus demonstrations toiintegration of a hybrid fuel cell bus fleet into daily routine operations of a transit system
- Sufficient size to place sustained, long-term demand on operations, maintenance and fuelling activities
- Evaluate operational performance of a hybrid fuel cell bus fleet

Slide 8:
**Funding Concept**
- BC Transit will contribute the cost of purchase andoperating 20 diesel buses
- Incremental funding from other government sources
- Contribution from industry

Slide 9:
**Area of Operations**
- 20 hybrid fuel cell buses operating in normal revenue service
- Initial deployment to Victoria Regional Transit System in 2008
- Subsequent deployment to Resort Municipality of Whistler in 2009
- Duty cycle for selected routes to be determined by the end of June 2005

Whistler Route Map

Slide 10:
**Feasibility Study Schedule**
- Kick off meeting –17 Jun 05
- Request for Information Issued –17 Jun 05
- Response to RFI –31 Aug 05••Feasibility Study completion –30 Sep 05
- Business Plan completion –31 Oct 05••Funding confirmed –Mar 06

Slide 11:
**Proposed Procurement Process**
- Prime contractor for each of buses and fuel facilities
- Request for Expressions of Interest and Statement of Qualifications –1 Dec 05
- Responses due -28 Feb 06
- Request for Proposals –31 Mar 06
- Responses –31 May 06
- Contract award –NLT end Jun 06

Slide 12:
**Proposed Milestones**
- Whistler facility upgrades –fall 2007
- Victoria facility upgrades –spring 2008
- Victoria fuel facility –spring 2008
- Buses delivered to Victoria –summer 2008
- Whistler fuel facility –spring 2009
- Buses to Whistler –summer 2009

Slide 13:
**Bus Specifications**
- Seated capacity –39
- Max passenger capacity –no less than 60
- Fully accessible low floor –75% acceptable
- Range –minimum of 500 km
- All other specs to meet or exceed standards for diesel buses
- Required availability for service –80%
- to be stored outside when not in use

Slide 14:
**Power Train Conversion**
- After completion of useful service and evaluation, stack replacement or conversion
- Design must allow for conversion to other commercially available power train if original does not meet expectations

Slide 15:
**Bus Warranty & After Sales Service**
- As for any other bus –manufacturer responsible
- 1 year bumper to bumper
- 5 year power train
- Fuel tank certification –5 years

Slide 16:
**Fuelling System**
- Production capacity –1,000 kg/day minimum (based on 40 –50 kg/bus/day average)
- Fast fuelling –8 to 10 minutes/bus
- Turnkey operation –transit pays at nozzle
- Technology –best for application
- Ideally co-located with CNG fueling
- Phased installation in Victoria and Whistler with simultaneous fuelling at both sites during transition
- Two day reserve of daily demand required on site

Slide 17:
**Infrastructure Upgrades**
- Maintenance facilities at Victoria and Whistler responsibility of BC Transit

Slide 18:
**Training and Documentation**
- Operations, Maintenance and Refueling training to be developed and provided by suppliers
- Training of first responders -suppliers
- Documentation of unique maintenance policies, procedures and processes
- Documentation of fueling infrastructure and processes

# **Annex D:** Request for Information

*WITHOUT PREJUDICE*

*REQUEST FOR INFORMATION*
*BC TRANSIT*
*HYBRID FUEL CELL BUS PURCHASE*

17 June, 2005

**Introduction**

1. The purpose of this request for information is to solicit valuable industry input to the feasibility study for the proposed Hybrid Fuel Cell Bus Fleet Purchase that will indicate how to meet the public policy, economic, technical and administrative challenges in a timely and logical manner.

2. The objective of the feasibility study is to develop the business case to integrate a large scale "pre-commercialization" fleet of fuel cell buses into BC Transit's regular operations.

3. Input received from industry will assist in developing the essential management strategy that will guide the process from the initial stages of project definition to financial analysis and funding requirements, specification development, codes and standards, procurement, training and community outreach to implementation of "on street" service.

4. The study will:

   - Serve the needs of the Canadian Transportation Fuel Cell Alliance (CTFCA), federal and provincial governments, and industry to adopt hydrogen and fuel cell technology and its ability to provide a sustainable transportation solution
   - Frame the engineering issues and challenges facing the project, outline the means to meet them and define the time frames for doing so

5. This request for information is not part of any procurement process and its results will not constitute any part of a future contractual document.

**Information Requested**

6. Respondents are invited to review the concept for the proposed hybrid fuel cell bus project presented at the meeting of potential suppliers on 17 June, 2005, at Whistler. B.C., and submit comments and information on the topics below.

7. Bus and Bus Components
   a. Concept. Is the concept presented realistic and achievable? If not, please present alternative recommendations.

b. Interest.

- Are you as a potential supplier interested in participating in the proposed project, funds being available?
- Would you participate as a prime contractor or as a sub-contractor?

c. Capabilities.

- What products or services is your company able to contribute to the project?
- What alternative solutions, if any, would you recommend?

d. Project Milestones.

- Are the milestones identified in the concept realistic?
- If not, why not?

e. Bus Specifications.

- Are the general bus performance specifications achievable?
- If not, why not? What alternatives would you recommend?
- What performance limitations are there or could there be for a hybrid fuel cell bus?
- What is an estimated capital cost for manufacturing 20 hybrid fuel cell buses, broken down by percentage into: glider cost; fuel cell stack cost; drive train; other components; engineering and integration; documen tation; and after sales service and warranty?
- What is the percentage incremental annual maintenance cost (broken into labour and material components) over that of 2007 clean diesel technology?
- What is the anticipated fuel efficiency of a hybrid fuel cell bus in terms of kms/kg hydrogen?
- Would financial commitments over and above the industry norm would you require entering into a contract to build 20 hybrid fuel cell buses?
- What performance or other technical limitations would a proposed hybrid fuel cell bus have (e.g. grade climbing ability, duration of climb, etc.)?
- Will proposed hybrid fuel cell technology operate effectively in the climate range of Whistler?
- What generation of fuel cell stack would be proposed?
- What is the expected service life of suggested fuel cell stack before major rebuild or replacement?
- What are the anticipated replacement costs for the fuel cell stack after expiration of the warranty period?
- What certification rating will fuel tanks have (5,000 psi or 10,000 psi) and what would the cost differential be to meet the stated bus range performance specification?
- What would be the expected life of selected fuel tanks?

f. Technology Conversion. The concept described made provision for converting the hybrid fuel cell bus into another commercially available technology at the time of stack overhaul/replacement, or sooner if expecta tions are not met in practice.

- Is it feasible to design the bus to allow future conversion to another technology such as diesel electric hybrid?
- What challenges would this place on the design?
- What additional capital cost would this incur?
- What alternatives are there if the hybrid fuel cell technology does not meet expectations?

g. Warranty.

- Are the warranty periods identified in the concept achievable?
- If not, what are alternatives proposed?
- Is the bus prime contractor prepared to take on responsibility for all warranty issues related to the vehicle?
- If not, why not? What limitations would there be?
- What incremental cost would there be to meet the desired warranty periods?

h. Operation and Maintenance Training

- What unique skill sets are required to operate a hybrid fuel cell bus, if any?
- How long will operator training be?
- What is the cost of developing and delivering operator training?
- What unique skill sets, over and above those required for a diesel mechanic, are required to maintain a hybrid fuel cell bus?
- How long will maintenance training be?
- What is the cost of developing and delivering maintenance training?

8. Fueling Station and Components

a. Concept. Is the concept presented realistic and achievable?

b. Interest.

- Are you as a potential supplier interested in participating in the proposed project, funds being available?
- Would you participate as a prime contractor or as a sub-contractor?
- Are you prepared to build the required fueling stations and finance them using the downstream billings of use using an agreed “nozzle cost” per kg of hydrogen? What are alternative financing mechanisms?

c. Company Capabilities.

- What products or services is your company able to contribute to the project?
- What alternative solutions, if any, would you recommend?
- Is an environmental assessment required?

d. Project Milestones.

- Are the milestones identified in the concept realistic?
- If not, why not?

e. Fueling Facility

- Are the fuel production capacity and fueling times achievable? If not, why not?
- What hydrogen generation technology is recommended and why?
- Are you able to deliver hydrogen at the purity required by the fuel stack manufacturer?
- What space is required for installing the proposed fueling station?
- Will the fueling facility require any special construction techniques to allow it to operate effectively in Whistler's climate range?
- What is the estimated “nozzle price” per kg of hydrogen, including capital cost amortization, taxes, and annual maintenance costs, that would permit a turn key installation?
- What is the estimated capital cost of the required fueling facility?
- What is the estimated annual maintenance cost (broken into labour and material components) for the fueling facility?
- What back-up will be provided should the primary generating capability fail?
- What limitations will there be for the siting of a fueling facility? Are there any environmental issues that will need to be addressed?
- What issues are raised by co-locating the hydrogen fueling station with a CNG fueling station, if any?
- Could a fueling facility built for Victoria be transferred to Whistler in stages, while still permitting fueling to take place in both locations? What would be the incremental capital cost?

f. Fueler Training

- How long will it take to train vehicle service personnel on the operations and safety issues related to fueling buses?
- What is the anticipated cost of this training?

**Format for Responses to Request for Information**

9. Interested potential suppliers should respond to those questions above for which they are qualified, using the same sequence of numbering and presentation as above. Any additional information should be added to the end of submission submissions.

10. Questions generated during completion of responses to this request for information may be directed, in writing by e-mail, to Ron Harmer at ron_harmer@bctransit.com or by phone at (250) 996-5663

### Submission of Responses

11. Completed responses are to be submitted no later than 31 August, 2005, to:

> Mr. Ron Harmer, P. Eng.
> Vice-President Technical Services
> BC Transit
> 520 Gorge Road East
> Victoria, B.C., V8T 2W6

### Conclusion

12. The completion of the feasibility study is essential to getting funding support from various levels of government. Only when the project is clearly defined and a business plan developed for its implementation will funding be requested and confirmed.

13. Thank you in advance for participating in this important endeavour in helping to turn the vision of hydrogen powered fuel cell transit fleets into reality.

Ron Harmer
Vice-President Technical Services
BC Transit
250-995-5663

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BC Transit

For Questions and Comments,
contact:
Ron Harmer, Vice-President, Technical Services
BC Transit
520 Gorge Road East
Victoria, BC  V8W 2P3
250-995-5663