Towards a National Hydrogen & Fuel Cell Strategy:
A Discussion Document for Canada

Government of Canada
Gouvernement du Canada

Canada

For information regarding the Government of Canada's involvement in the hydrogen and fuel cell sector, visit Canada's Hydrogen and Fuel Cell Committee's Hydrogen Economy Portal at www.hydrogeneconomy.gc.ca

To learn more about hydrogen and fuel cell technology and applications, visit the Learn More section.

This publication is available electronically on the World Wide Web in HTML format at the following address: www.hydrogeneconomy.gc.ca

Aussi offert en français sous le titre Vers une Stratégie nationale sur l'hydrogène et les piles à combustible : Un document de discussion pour le Canada.

Cat. No. Iu4-94/2005E-PDF
ISBN 0-662-42228-7
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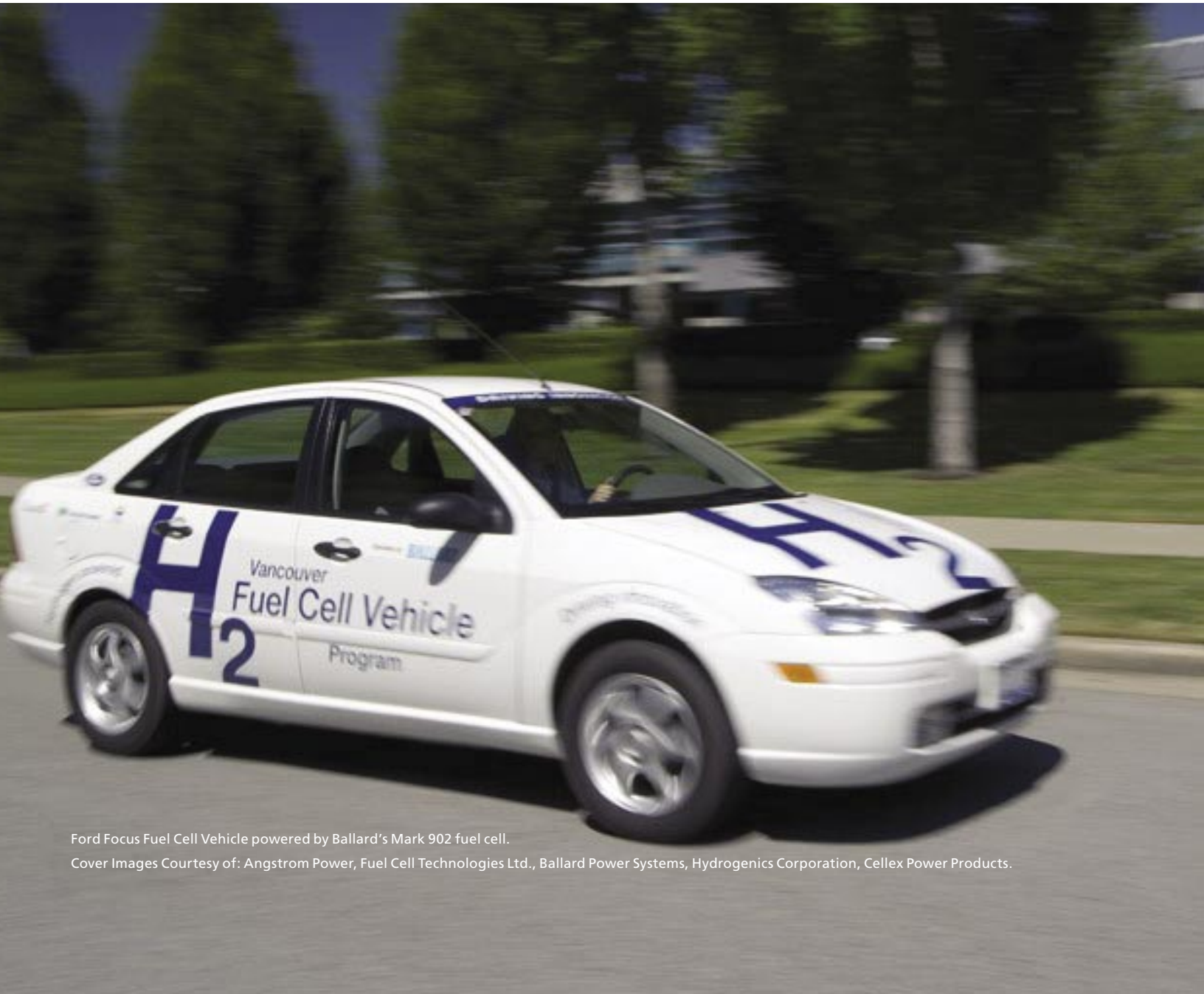

Ford Focus Fuel Cell Vehicle powered by Ballard's Mark 902 fuel cell.

Cover Images Courtesy of: Angstrom Power, Fuel Cell Technologies Ltd., Ballard Power Systems, Hydrogenics Corporation, Cellex Power Products.

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Buses powered by Ballard fuel cell engines successfully completed two years of field testing in 2000. During these tests in Chicago, Illinois, USA and Vancouver, British Columbia, Canada, 6 buses carried more than 200,000 passengers and traveled over 118,000 kilometers (73,000 miles).

Source: Ballard Power Systems.

Executive Summary

The transition to a new world energy paradigm offers Canada a multitude of opportunities for benefiting from global energy markets and for contributing to environmental, economic and social progress both at home and abroad. In this new economy, hydrogen as an energy carrier with fuel cells as enabling technology, will help extend the supply of fossil fuels and optimize the use of renewable energy sources.

This Discussion Document represents a key step toward formulating a National Hydrogen and Fuel Cell Strategy, together with an action plan, that will help us achieve our potential in a hydrogen-powered world. It does not seek to hand down preconceived solutions, but rather to formulate questions whose answers may help us frame the strategy and action plan in a realistic way. It is intended to identify and prioritize opportunities, to engage all stakeholders in a concerted effort to address the needs of the sector, and to select the most effective short-term actions that stakeholder groups can take to meet Canada's overall objectives for the sector.

Where Canada is Now

Canada is now well positioned for a transition to a new energy economy. We are leaders in key areas of fuel cell development, possess abundant resources for developing a hydrogen infrastructure and have numerous industry clusters with advanced R&D capabilities.

Capitalizing on these advantages, however, will require sustained support for Canada's fuel cell and hydrogen-related companies as they develop products and services for the energy marketplace. Early action, such as increased R&D support, increased public awareness and better access to capital, would help ensure Canada's leadership in the evolving hydrogen future. Identifying immediate market opportunities, exporting products and expertise, and using partnerships to strengthen our position are all necessary to achieving this goal.

The Hydrogen Future: Vision and Benefits

Hydrogen's value proposition can be seen in terms of the benefits accruing from clean energy systems, sustainable growth and environmental stewardship. For Canada, the vision of a hydrogen future includes a cleaner and more reliable electricity supply, major economic returns from the manufacture and export of hydrogen and fuel cell products, and a better quality of life for Canadians in general. On a global scale, the hydrogen future encompasses a lower dependence on fossil fuels, decreased greenhouse gas emissions and sustainable growth for the industrializing world.

A crucial step toward realizing this vision is to create a National Hydrogen and Fuel Cell Strategy.

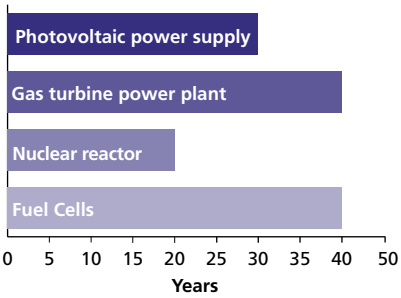


Figure 1. Time Gap Between First Application and Commercialization

Numerous examples from the history of power production illustrate the large time gaps that exist between the first application of a new power technology and its large-scale commercialization.

Source: Our Hydrogen and Fuel Cell Future. www.hydrogeneconomy.gc.ca

Canada'a Hydrogen and Fuel Cell Committee (H2FCC)

The government-established H2FCC is co-chaired by Industry Canada and Natural Resources Canada. It represents 21 federal departments and agencies, and oversees the federal government's actions and initiatives in the hydrogen and fuel cell sector in order to achieve full-scale commercialization of the technology.

The H2FCC supports research and analysis aimed at improving knowledge and understanding of Canada's transition to the new energy paradigm. It sets priorities and coordinates the hydrogen-related activities of federal departments, agencies and programs; monitors and reports on federal interdepartmental initiatives; and represents Canada in several international strategic partnerships such as the International Partnership for the Hydrogen Economy and the International Energy Agency.

The H2FCC is helping to maintain Canada's leadership in this sector and is ensuring that we remain globally competitive as the hydrogen and fuel cell industry moves towards full-scale commercialization.

Canada's Hydrogen and Fuel Cell Committee (H2FCC) members, together with provincial, industrial and academic stakeholders, will be ultimately responsible for the plans, programs and activities that will comprise this strategy.

Canada's Global Opportunities

There are four chief areas in which Canada can potentially exploit major opportunities and benefits.

Hydrogen infrastructure

Possibilities include hydrogen capture from waste streams; electrolytic hydrogen production from hydroelectricity and renewables; steam methane reforming; storage, distribution and delivery systems; large-scale hydrogen production; and hydrogen production from gasification of fossil fuels and biomass.

Mobile applications

Mobile applications, such as hydrogen-powered automobiles, trucks, buses, locomotives and industrial vehicles, are expected to provide the critical mass market for hydrogen and fuel cell products. Gasoline-electric and diesel-electric hybrids, as well as hydrogen internal combustion engines, could be another important transitional technology for establishing a mass market for fuel cell automobiles.

Stationary power

Hydrogen-powered fuel cells can be used in a variety of stationary applications, including off-grid and backup power, residential electricity and heating, and distributed and centralized power generation. Canada could also build on its expertise with small stationary applications by developing new capacity in high-temperature fuel cells for large-scale power generation.

Portable power

In this sector, our early market opportunities lie in micro fuel cells for use in military applications and in personal applications such as laptop devices, cell phones and satellite communication handsets.

Actions to Strengthen the Industry

There are numerous early actions that we can use to take advantage of our opportunities and address priority issues. These actions fall into several key categories:

- research and development;
- demonstration and deployment;
- education, awareness and outreach;
- regulation; and
- coordination, analysis and promotion.

Canadian governments at all levels have a catalytic role to play in each of these categories, and can help establish fruitful partnerships among industry, academia and the research community.

Next Steps

To obtain input for developing this Discussion Document, Canadian Government representatives discussed directions and priorities with key stakeholders and experts in the sector. The Discussion Document represents the second step in a seven-step process of preparing and initiating a National Hydrogen and Fuel Cell Strategy.

The initial steps were to

- establish the initial direction and priorities for the strategy; and
- undertake the development of a Discussion Document and carry out early consultations with key stakeholders and experts.

The remaining steps are to

- engage in a broader consultation process;
- finalize the National Hydrogen and Fuel Cell Strategy;
- obtain Cabinet approval of the National Hydrogen and Fuel Cell Strategy and its proposed priorities;
- release the National Hydrogen and Fuel Cell Strategy; and
- implement the National Hydrogen and Fuel Cell Strategy's recommendations and monitor progress.

Canada's Need for a National Hydrogen and Fuel Cell Strategy

The transition to a new energy paradigm, together with Canada's world leadership in hydrogen and fuel cell technology, offers us unique opportunities for influencing global energy markets and contributing to environmental, economic and social progress at home and abroad. To take advantage of them, we need a clear vision of our role in the unfolding new energy paradigm, as well as an action plan that will guide the development of our hydrogen-related technologies.

The intent of the National Hydrogen and Fuel Cell Strategy is to develop this vision and this plan. The vision will cover the next 30 years of Canada's participation in the new energy economy, while the plan will set out the targets and deliverables for achieving the vision.

To shape our strategy, we need to examine Canada's opportunities in hydrogen and fuel cell markets, particularly in the context of our technology leadership and the global environment. The strategy itself will build on the work of Canadian governments, industry, universities, research institutions, NGOs and international partnerships. Its goal will be to coordinate their efforts and resources in ways that will best meet our national objectives.

Initially, the action plan will focus on short-term steps that will help the hydrogen and fuel cell sector achieve commercial success. Later, as markets evolve, the plan can be reviewed to determine whether it is meeting its targets and can, if necessary, be revised to remain consistent with market realities.

This Discussion Document represents a key step toward formulating a National Hydrogen and Fuel Cell Strategy that will help us achieve our potential. The document examines the strategic opportunities for Canadian industry in global and domestic markets, and proposes actions, institutional arrangements, and policy and regulatory actions that will enable us to make the most of these opportunities.

The Discussion Document does not seek to hand down preconceived solutions, but rather to formulate questions whose answers may help us frame the strategy and action plan in a realistic way. It is intended to identify and prioritize opportunities, to engage all stakeholders in a concerted effort to address the needs of the sector, and to select the most effective short-term actions that stakeholder groups can undertake to meet Canada's overall objectives for the sector.

Where We Are Now

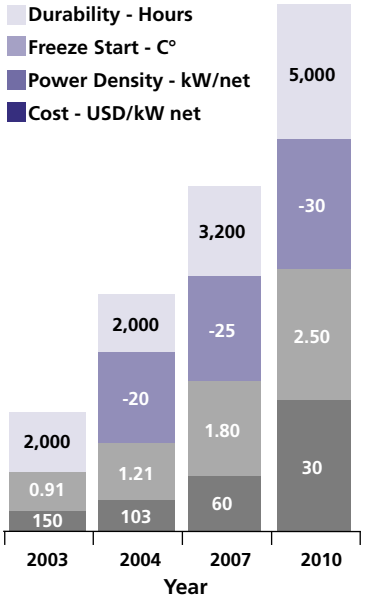


Figure 2 . Ballard's Technology Road Map

The Technology Road Map refers to four key automotive fuel cell performance targets: durability, freeze start, power density and cost. Meeting these targets will bring the automotive fuel cell to the point of commercial viability. Although progress has been made over the last five years, significant gaps remain to be closed.

Source: Ballard Power Systems.

Canada's Current Advantages

What equips Canada to be a leader in the transition to the new energy economy? In brief:

- Canada leads in the development and commercialization of Proton Exchange Membrane (PEM) fuel cells and small Solid Oxide Fuel Cells (SOFCs) for use in mobile, small stationary and portable power markets.
- We have significant capability in technology development for hydrogen production, purification and storage, as well as for fuelling infrastructure, testing and systems integration.
- We have growing hydrogen industry clusters across the country and our technologies and expertise are recognized around the world.

At the same time, we are now competing on a global scale. Our advantages may slip away if we do not take early action to sustain our hydrogen industry.

Sustaining Canada's Hydrogen Industry

Canadian companies require support while they develop products and services for the marketplace. Without such support, overcoming barriers of cost, performance and infrastructure may be impossible. Access to financing is a particular hurdle because of the intensive R&D and long development times required for commercialization.

Transportation applications can have the largest environmental, social and economic impacts. However, significant reliability improvements and cost reductions must still be achieved before this can happen. According to the US Department of Energy (DOE) timeline[1], the commercialization of major transportation applications, such as passenger cars, is at least 10 years away.

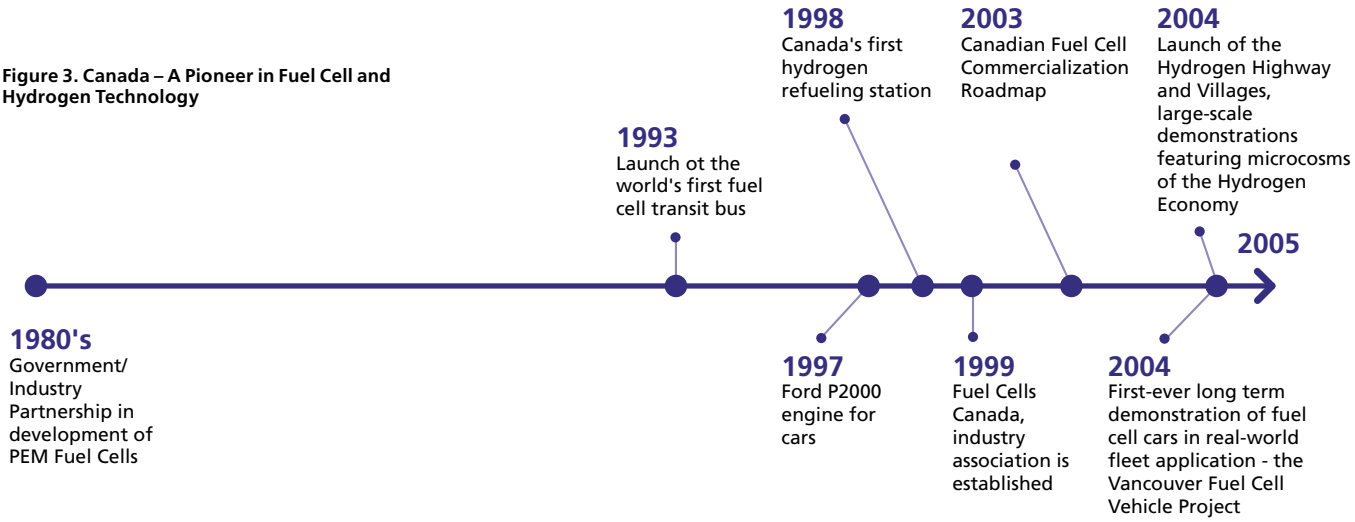
Canadian companies such as Ballard have made significant technological progress and are aligned with DOE commercialization timelines and technology targets. Ballard's technological performance related to fuel cell durability, lifetime and costs have made it the preferred fuel cell supplier for companies like General Hydrogen and Cellex.

Early action is essential for helping our industry though this phase, and could focus on:

- supporting R&D to achieve goals in technology development programs;
- pursuing immediate and near-term commercial opportunities;
- increasing access to capital;
- developing capabilities and fostering market adoption;
- developing skills, education and awareness; and
- developing codes and standards.

If we are unsuccessful in this phase of commercialization, we risk sacrificing many opportunities and benefits, and may end

Figure 3. Canada – A Pioneer in Fuel Cell and Hydrogen Technology



by importing hydrogen technologies we might have developed at home.

Identifying Our Immediate Economic Opportunities

The strength of our regional clusters and their anchor tenant companies, supported by major private and public investment, provides a sound platform for reaping the near-term benefits of this technology base.

The wide spectrum of potential applications also points to many longer-term opportunities. An expansive Canadian hydrogen industry could include mobile applications, stationary power sources and energy production, as well as technology for small-scale applications such as electronic devices.

Using Exports to Fuel Innovation

The hydrogen and fuel cell sector, like many other Canadian industries, depends on exports for its survival and growth. Although domestic sales can help companies develop products and gain footholds abroad, our industry clusters cannot survive without international markets.

To sustain Canada's hydrogen and fuel cell sector in this context, we need to be aligned with the global interest in adding hydrogen and fuel cell-related technologies to the energy mix. This will foster a market for our exports, which will stimulate technology innovation here at home. Such innovation will in turn lead to new, exportable products and services, which will generate export revenues, economic growth and other benefits.

The Role of Partnerships

During the past two decades, the Government of Canada has invested more than $200 million in the hydrogen and fuel cell sector. British Columbia, Alberta, Saskatchewan, Manitoba, Ontario, Quebec, New Brunswick and Prince Edward Island all continue to support industry developments in their respective regions.

Moreover, during the past five years, the private sector has also invested approximately $200 million annually in R&D. The international nature of the sector, combined with the small size of Canadian companies, has encouraged the Canadian industry to place a high priority on developing collaborative relationships with public and private organizations within and outside Canada; in 2004, as a result, Canadian entities reported 256 strategic alliances with a wide variety of organizations.[2]

Framing the Value Proposition

The market for hydrogen and fuel cell products and services will be driven by a variety of factors. These range from the need for cleaner energy systems to the appetite of consumers for new or enhanced products and services.

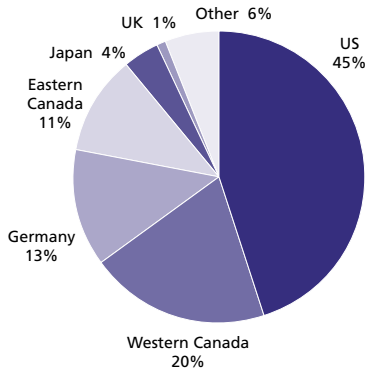


Figure 4 . Location of Canadian Technology Demonstrations

Source: Canadian Hydrogen and Fuel Cell Sector Profile 2004, Government of Canada, Fuel Cells Canada, PricewaterhouseCoopers.

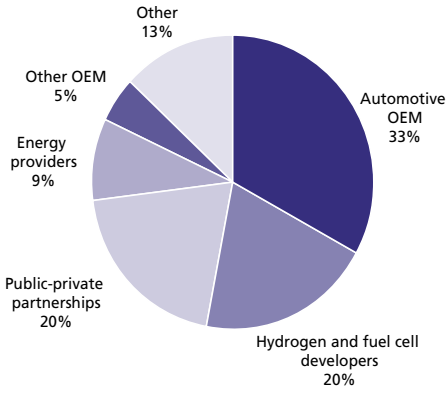


Figure 5 . Strategic Alliances

Source: Canadian Hydrogen and Fuel Cell Sector Profile 2004, Government of Canada, Fuel Cells Canada, PricewaterhouseCoopers.

Cleaner Energy Sources and Systems

While industrial development offers an immediate economic payoff for Canada, one long-term rationale for pursuing hydrogen and fuel cell technologies is that they can help "decarbonize" our energy system so that it produces clean energy and fewer emissions. This would mitigate climate change, reduce air pollution, increase energy security and contribute to the general public good.

Sustainable Growth

Another driver is the achievement of sustainable growth, which would balance economic, environmental and social needs in constructive ways. Already, for example, national governments are becoming much more concerned with the security of their energy supplies. The resulting search for alternative, sustainable energy sources will likely speed up the transition to the new energy paradigm. In this paradigm, hydrogen will be produced from a variety of different primary energy sources, while fuel cells, as the enabling technology, will play an important role in providing power for transportation, stationary and portable applications.

Environmental Stewardship

Canadians are experienced in the stewardship of vast natural resources, and we are already leaders in environmentally sound technologies. By exercising our stewardship on a global level, we could help other countries overcome their environmental difficulties while developing sustainable communities at home. The need for such a broad engagement is also a result of world-wide environmental issues such as climate change, as well as the growing demand and need for securing future energy supplies. In essence, Canada and the other developed countries have a responsibility for global stewardship.

At the same time, if we are to maintain our credibility as environmental stewards, we will have to act appropriately in our cities and communities.

An Integrated North American Energy Market

Canada and the United States face similar concerns about their growing demand for energy, and about the security and reliability of their energy supplies. Adopting a continental focus for the new energy paradigm would allow our two countries to share development costs and form strategic alliances for entering world markets.

In fact, the US and Canada are already exploring ways to create an integrated North American hydrogen and fuel cell market. In 2004, a joint statement by both countries called for expanded partnerships to promote the clean and efficient use of energy resources. In April 2005, Canada's International Policy Statement: A Role of Pride and Influence in the World further articulated the goals of North American market integration.[3]

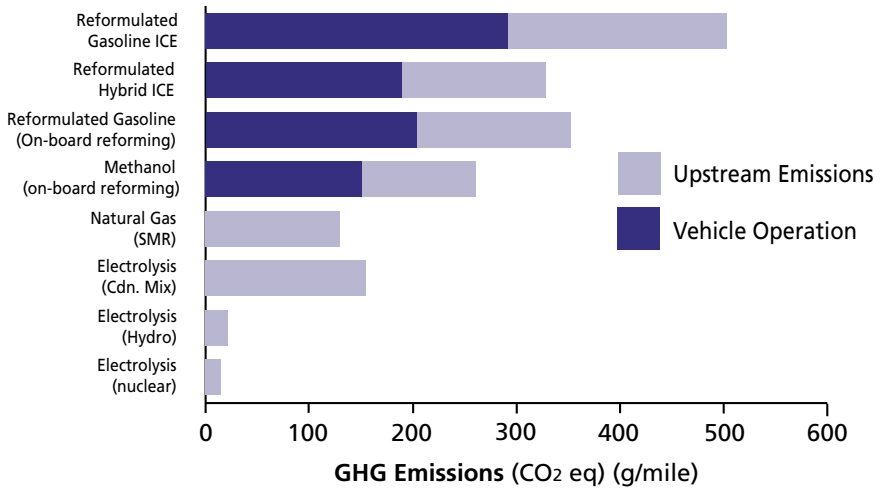


Figure 6. Impact of Hydrogen Fueling Pathway Choice on GHG Emissions From Fuel Cell Vehicles

Source: Natural Resources Canada, 2005.

Short-term Factors in the Value Proposition

Climate change, the depletion of oil resources and the need for sustainable growth are major elements of the hydrogen value proposition, but environmental concerns may not be sufficient to drive the industry during the immediate future. During the short term, for example, a key factor in the value proposition may be the benefits it offers to the average consumer, such as the manufacture of new kinds of consumer products and enhancements to existing ones.

Other short-term value factors and market drivers may arise from the technology in unexpected ways, just as the opening of the Internet to public use in 1995 led, within a very few years, to the explosive growth of e-commerce. Furthermore, marked increases in productivity and competitiveness of early adopters of hydrogen and fuel cells—such as warehouses employing more efficient forklifts powered by fuel cells—will ultimately help substantiate the short-term value proposition for hydrogen and fuel cells.

Bringing the Benefits Home

What will Canadians gain from a new energy paradigm, both during the transition period and when it becomes fully established? Here are some possibilities:

Economic Benefits

Canadian cities could serve as launch pads for hydrogen and fuel cell products that would be marketed globally. Our cities could also become early-adopter communities, furnishing innovative and environmentally preferred urban models to be replicated elsewhere.

A new, balanced energy mix of hydrogen and current energy sources could benefit Canadian industry by providing reliable energy solutions, establishing stable electricity supplies and lowering manufacturing input costs. Distributed networks, based on environmentally preferable energy systems, could provide clean and efficient power and increase the reliability of the energy supply in both rural and urban areas.

Canadian firms could develop a variety of hydrogen production, storage, distribution and conversion technologies to become the world's first manufacturer and exporter of commercially viable hydrogen and fuel cell products.

Through the strength of our regional industry clusters, we could become a world-recognized centre of excellence for hydrogen technologies. This would enhance our competitiveness and would help us become one of the world's most innovative and productive countries.

Hydrogen and fuel cell products could reduce energy costs in remote and northern communities, helping to create and support new jobs and services. In Canada's larger centres, consumers and businesses could enjoy the convenience of having power supplies close to their homes, offices and factories.

Social and Environmental Benefits

Canada's leadership and active role in the transition to the new energy economy could generate a better quality of life for Canadians and provide the capacity we need to support our social goals.

Canada could become a steward of the environment, helping to mobilize international efforts to cope with global environmental problems.

Hydrogen-based energy systems would reduce the world's dependence on fossil fuels, extending the supply of these valuable resources and decreasing our vulnerability to political and military conflicts in oil-producing regions worldwide.

Global conversion to clean, hydrogen-based energy systems would lower levels of GHG emissions and help mitigate the effects of climate change.

Access to inexpensive sources of clean energy would drive the sustainable economic growth needed to improve the lives of people in the industrializing world.

A new global energy economy will bring about marked improvements in the quality of the world's air and water, leading to better health for everyone.

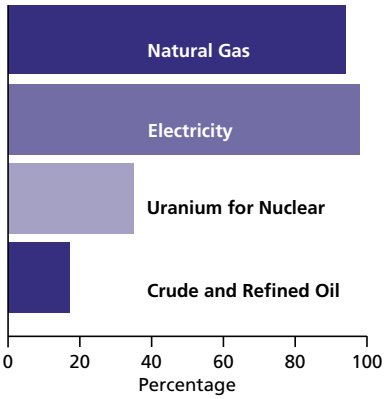


Figure 7. US energy imports from Canada as a percentage of total US energy imports (2002)

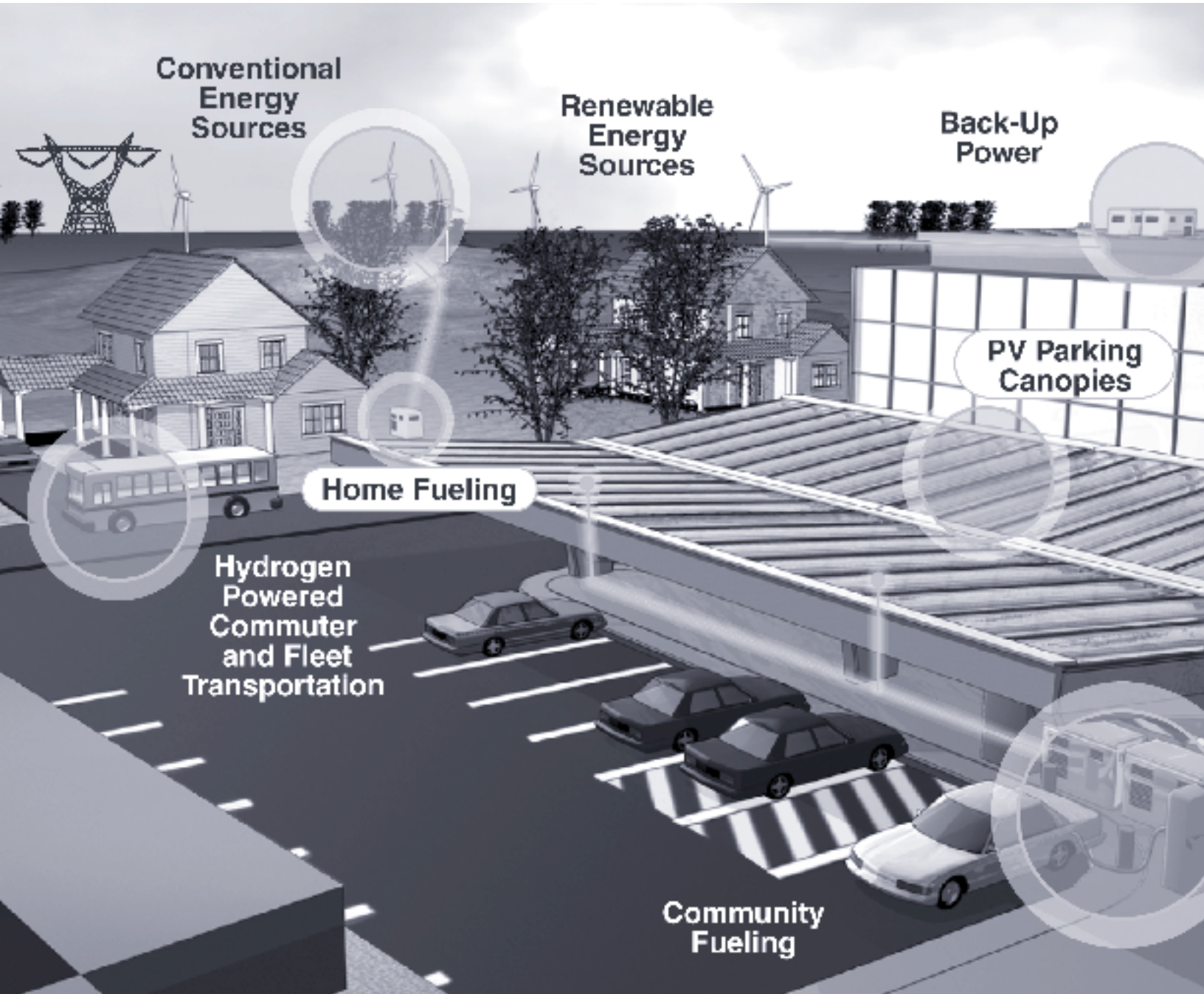
Canada was the largest foreign supplier of oil to the US again in 2004, for the sixth year running. In 2002, Canada supplied the US with 17 percent of its crude and refined oil imports — more than any other foreign supplier at over 1.9 million barrels per day.

Source: International Trade Canada.

Residential and Commercial Hydrogen Concepts

"Biggest change in the energy economy since electricity and the gasoline automobile"

Source: General Electric Global Research.



A Vision of Our Hydrogen Future

What would a hydrogen powered world look like?

Certainly it is a much cleaner and quieter place than the one we now inhabit, for by 2075, hydrogen has become the energy carrier of choice. Fuel cell systems are as pervasive as electricity grids and internal combustion engines once were, but vehicles generate energy with a minimum of pollution and move people and goods with nearly silent electric motors. The air over the world's great cities is clear; people breathe more easily. Climate change, while still inevitable, is taking place more slowly and we have gained the time we need to adapt to it.

In Canada, hydrogen and fuel cell systems are contributing to a strong economy and a healthy, vibrant society. Through the sustained efforts of governments and industry, we have established multiple pathways for hydrogen production that now depend largely on environmentally preferable energy sources. Hydrogen has been fully integrated into our energy mix and is used across the country for mobile, stationary and portable applications. Our hydrogen and fuel cell industry is recognized for its excellence around the world, and our fuel cells and hydrogen technology are the products of choice for purchasers everywhere. We have been, and continue to be, pioneers of the hydrogen age.

If we can realize this vision, history may record the development of hydrogen-based energy systems as one of the 21st century's most significant achievements. For Canada, a crucial step in this development is to create a National Hydrogen and Fuel Cell Strategy that will help us better understand how hydrogen and fuel cells can help make the vision a reality.

From Vision to Reality

Canada's Hydrogen and Fuel Cell Committee (H2FCC) members, together with provincial, industrial and academic stakeholders, are ultimately responsible for the plans, programs and activities that will comprise the National Hydrogen and Fuel Cell Strategy. In collaboration with industry and with provincial, municipal and international stakeholders, the strategy would be implemented in a coordinated and timely way and would be periodically adjusted to reflect changing conditions.

A stakeholder group representing the public and private sectors could be established and could meet annually to discuss the progress being made. The H2FCC could oversee this group and develop a report for the appropriate Ministers each year.

Some specific objectives that would move us toward these goals are as follows:

- By 2010, become the first nation to commercialize end-user and consumer products based on hydrogen and fuel cell technologie.
- By 2010, realize profitability in at least five Canadian hydrogen and fuel cell firms.

A Vision for Canada:

Canada will provide global leadership in the supply and demand for sustainable energy systems utilizing hydrogen as an energy carrier and fuel cells as an enabling technology to ensure economic, environmental, and social sustainability both at home and abroad.

- By 2012, become one of the top three countries, on a per-capita basis, to utilize hydrogen and fuel cell applications.
- By 2012, reduce CO_2 emissions by 1MT from current energy and hydrogen supply systems.
- Implement effective policy incentives for customers of hydrogen-related technologies.
- Establish Canada as a recognized world centre of excellence for PEM fuel cell R&D.

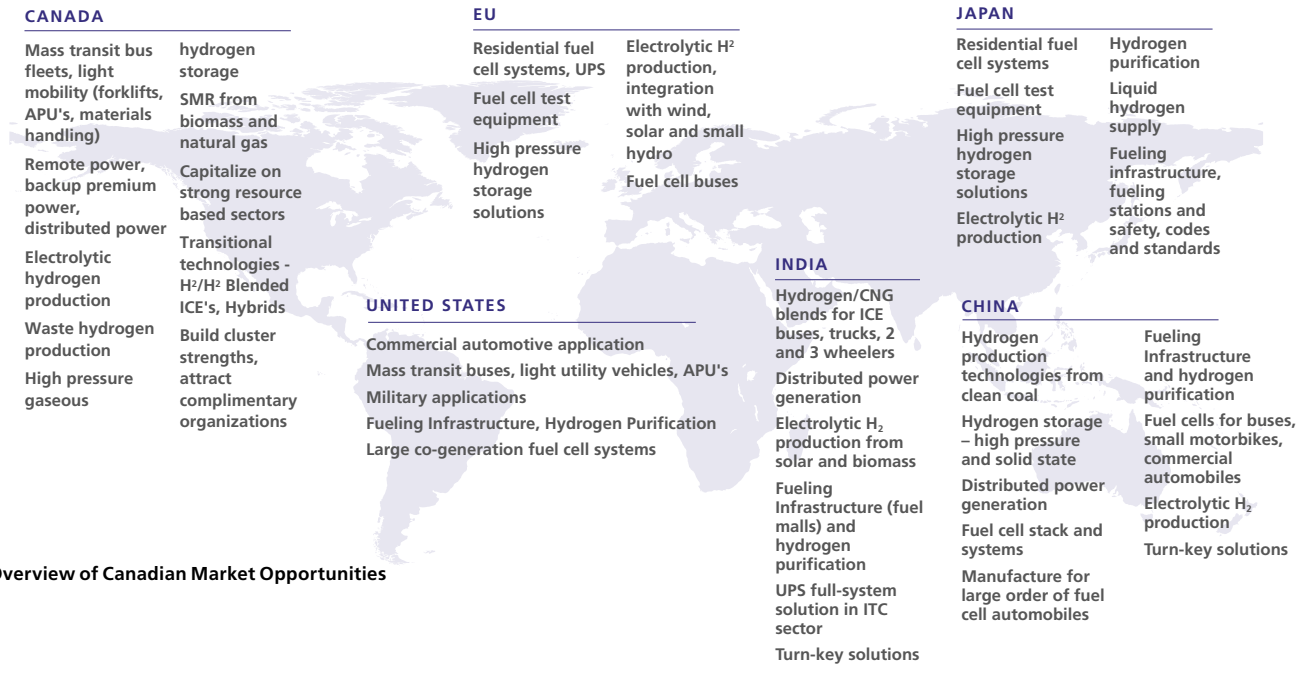
The overriding goal of this vision is to advance Canada's economic, environmental and social objectives through a concerted effort to accelerate the transition to the new energy paradigm at home and abroad. Success will demand sustained, vigorous action, but it is within our reach if we commit ourselves to achieving it.

Vision: Questions for the short term

Is this the right vision for Canada?
What should Canada's adoption targets be in:

- number of pre-commercial and commercial units in mobile, stationary, portable applications and hydrogen stations?
- percentage of installed power?
- percentage of energy production?

Canada's Opportunities in a Global Hydrogen Future



Overview of Canadian Market Opportunities

A wide range of strategic business and development opportunities, including hydrogen infrastructure, transportation systems and stationary and portable energy sources, are associated with the development of a Canadian hydrogen future. The short- and medium-term possibilities (2005-2015 and 2015-2025 respectively) are naturally more predictable and easier to identify than the longer-term opportunities from 2025 to 2035. Even so, we should try to identify as many of them as we can.

We must, of course, find a balance between our pursuit of shorter-term opportunities and our commitments to longer-term ones. Examining the following general questions may help us find ways to achieve such a balance:

- Which existing Canadian hydrogen and fuel cell technologies or applications hold the most short-term promise, and in which markets?
- Which mid- and long-term technologies, applications and R&D priorities are needed to build a sustainable hydrogen and fuel cell industry?
- How can Canadian technology and applications align better with our major export markets over both the short and long terms?

There are four major areas in which these questions apply: hydrogen infrastructure, mobile applications, stationary power and portable power. We will examine these in detail below.

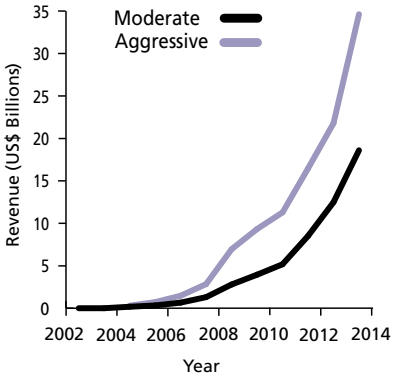


Figure 8. Global Fuel Cell Market Potential Projections: 2004 - 2013

The Sacré-Davey Project

Under the Hydrogen Highway™ initiative, a consortium led by Sacré-Davey Innovation, Sacré-Davey Engineering and Westport Innovations is carrying out a three-year Integrated Waste Hydrogen Utilization Project to capture a waste hydrogen stream in North Vancouver. The project will demonstrate Canada's world-leading abilities in hydrogen purification, fuelling station and mobile and stationary power technologies.

Photo: B. Stanley/Industry Canada

Hydrogen Infrastructure

Canada's current hydrogen infrastructure comprises facilities for hydrogen production, purification, storage and distribution. However, it will need major investments before it can meet the demands of a hydrogen future, and sustaining it at that level will require substantial industrial and consumer markets. This raises various "chicken-and-egg" problems; supporting a Canada-wide hydrogen fuelling infrastructure, for example, will depend on the mass consumer adoption of hydrogen vehicles—but few consumers will buy these vehicles until such an infrastructure is widely available.

While such problems are real enough, we should remember that we have solved them before. In the early 20th century, for instance, as more and more people bought automobiles, gasoline stations began to pop up across North America. Astute and determined leadership, from both the public and private sectors, could help ensure that hydrogen transportation repeats this success.

Infrastructure: Our Strengths

Canada has numerous strengths in this area:

- We are the largest per-capita hydrogen producer in the Organization for Economic Co-operation and Development (OECD).
- We have a diverse energy resource base offering multiple hydrogen production pathways, including many environmentally preferable sources with low GHG impacts.
- Because of the expanding requirements of the oil sands, Canada will become one of the world's largest hydrogen producers.
- Many of our regions have particular energy strengths, such as coal, oil, natural gas, hydroelectricity, nuclear power and wind.
- We have technological advantages in electrolytic hydrogen production and in steam methane reforming (SMR).
- We lead in developing, manufacturing and testing the high-pressure hydrogen storage cylinders used in most of the world's fuel cell vehicle and bus demonstrations.
- We have significant experience in end-use applications and are participating in more than 60 hydrogen fuelling demonstrations worldwide.[4]

Fueling a Hydrogen/CNG truck at the Powertech Labs Station in Surrey, BC.

Source: Powertech Labs.

Infrastructure: Choosing Short-term Priorities

We have several possibilities here.

Hydrogen capture and purification from waste streams

One immediate opportunity is to supply hydrogen from surplus production at salt electrolysis plants. The hydrogen would require purification for use in fuel cell systems and internal combustion engines. To achieve this, we could

- build on the success of Canada's first waste hydrogen capture project (see sidebar), and export this technology; and
- develop capture and purification technologies for biomass-based hydrogen production, such as reformation of bio-gas, and export these as well.

Electrolytic hydrogen production

Cost-effective electrolytic hydrogen technologies could be a priority because they enable distributed hydrogen generation and can use electricity produced by renewable, emission-free sources. Canada is already a R&D leader in this field and could build on this to

- produce hydrogen at competitive prices from existing hydroelectricity and nuclear plants, and from renewable energy sources such as wind; and
- market this technology to countries where electric power may become an important hydrogen source.

Steam methane reforming (SMR)

SMR from fossil sources is currently the chief hydrogen production technology in Canada. Small-scale SMR could facilitate distributed hydrogen generation and mobile applications, but the process's GHG emissions would need to be addressed. Even with this caveat, however, we could

- focus on R&D for small- and large-scale SMR, together with technologies for gas separation and purification, and for CO_2 capture and sequestration;
- for the domestic market, concentrate on SMR from natural gas and from gasification of biomass and coal; and
- combine our hydrogen expertise with our CO_2 sequestration expertise to offer a packaged solution.

Distribution and delivery

Opportunities may lie in building infrastructure both for small-scale, localized production facilities that need no distribution systems, and for larger, centralized producers that will distribute hydrogen via truck, rail or pipeline. Here we could

- build on our experience with hydrogen and compressed natural gas (CNG) technologies to improve the cost and performance of similar systems for hydrogen;
- at home and abroad, participate in the development of "clean fuel malls" that combine the dispensing of hydrogen, CNG, liquefied natural gas (LNG) and natural gas-hydrogen blends;
- continue technology development in areas ranging from hydrogen shipment containers to pipeline materials; and
- build on the number of dedicated hydrogen stations currently being demonstrated in Canada.

The Prince Edward Island Wind-Hydrogen Village

Hydrogenics Corporation and the Prince Edward Island Energy Corporation are leading Canada's first demonstration of electrolytic hydrogen production from wind energy. The three-year project will develop a hydrogen energy station and wind power facilities, with future phases to include a hydrogen fuelling station, hydrogen shuttle buses and a hydrogen-powered tour boat.

Wind power can play a particular role in advancing hydrogen infrastructure, since water electrolysis is the ideal "dump load" for wind-generated electricity during low demand periods.

Photo: Hydrogenics Corporation.

Infrastructure: Questions for the Short Term

Should Canada continue to pursue all pathways for hydrogen production, or specialize in a smaller number of carefully selected ones?

What supporting technologies, such as CO_2 capture and storage, could we co-develop for our chosen pathways?

Once the pathways are selected, which opportunities and tactics will allow us to build production, delivery and storage infrastructures for them?

Once the pathways are selected, how do we establish Canada in the export markets related to them?

Could the expansion of large-scale hydrogen production for oil sands provide infrastructure for fuel cell deployment and early adoption?

Fumes to Fuels

Fuel Cell Technologies (FCT) of Kingston, Ontario is working with Ford to demonstrate a process that uses the volatile organic compounds created in the automobile painting process to produce hydrogen, which in turn will fuel a 5 kW solid oxide fuel cell.

FCT is providing Ford's Dearborn, Michigan plant with the fuel cell. This system has tremendous pollution abatement potential for automobile manufacturing, because it reduces natural gas consumption as well as the emission of NO_x, SO_2, CO_2 and volatile organic compounds. The system also provides independent power generation for the plant.

Photo: Fuel Cell Technologies Ltd.

Storage

Hydrogen storage is a key enabling technology for a vast range of applications. In vehicles, for example, we need on-board energy storage that will provide a range comparable to that of gasoline vehicles (about 480 km). We could

- build on our leadership in high-pressure hydrogen storage for both domestic and export use;
- use our capacity in solid-state storage to improve metal-hydride storage technologies; and
- develop our capacity in low-pressure storage technologies such as carbon nanotubes.

Fuel cell test equipment

Canada's leadership in this market can allow us to help develop the benchmarking specifications, methodologies and evaluation protocols needed to establish codes, standards and regulations for the new energy paradigm. Here we could

- support industry R&D efforts in testing and diagnostics, including testing for hydrogen fuel quality; and
- become known worldwide as a centre of excellence for testing and diagnostic tools, thus supporting fuel cell development and creating early revenue streams.

Infrastructure: Choosing Medium- to Long-term Priorities

Major possibilities lie in the area of hydrogen production, as outlined below.

Large-scale hydrogen production

Large-scale, centralized hydrogen production and supporting infrastructures could become economically viable. We could consider

- using nuclear energy to support production processes such as high-temperature electrolysis and thermochemical water splitting;
- and developing new pipelines or adapting existing ones to transport hydrogen across the country.

Gasification of fossil fuels and biomass

Longer-term development could shift hydrogen production from SMR to the gasification of fossil fuels and biomass. Gasification, combined with CO_2 capture and storage, could make excellent use of our abundant energy resources while dramatically reducing GHG emissions. Several possibilities exist:

- We could develop gasification technologies for our major fossil fuel resources, including sub-bituminous and lignite coal, coke, heavy oil and bitumen.
- We could develop gasification, pyrolysis, bio-oil reforming and other technologies to produce hydrogen from biomass such as agricultural residues.
- Major opportunities exist for exporting these technologies to countries whose future energy supply will depend on coal and biomass, including India and China.

Infrastructure: Questions for the Medium & Long Term

Which opportunities will encourage the rational development of hydrogen infrastructure?

What resources should we devote now to these opportunities?

To what extent could new primary energy resources for hydrogen production, such as biomass and biological methods, be developed on a regional basis to meet economic and emission objectives?

Should the research community be engaged to develop low pressure hydrogen storage technologies?

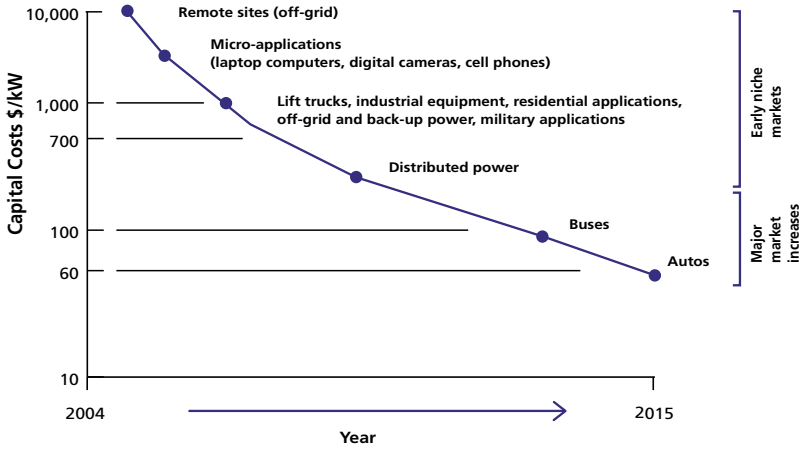


Figure 9. Commercialization Timeline

Source: Graph adapted from Methanex, September 2002, Industry Canada

Mobile Applications

Mobile applications, such as hydrogen-powered automobiles, trucks, buses, locomotives and industrial vehicles, are expected to provide the critical mass market for hydrogen and fuel cell products. The development of this market is being driven by global concerns about air pollution, GHG emissions and energy security and diversity.

Canada has a 20-year history of developing hydrogen and fuel cell technologies for both light- and heavy-duty mobile applications. The US is a major market prospect for these technologies, but developing markets like China and India could also be enormous.

Mobile Applications: Our Strengths

We have several advantages in this field:

- We are pioneers and world leaders in PEM fuel cell technology for mobile applications.
- We have a dominant share of the global market for the fuel cell systems now being demonstrated in light- and heavy-duty vehicles, such as buses, and in off-road industrial vehicles, such as forklifts.
- We enjoy expertise in hydrogen and blended-fuel internal combustion engine (ICE) technologies, subsystems and components.
- We have gained valuable experience through our participation in more than 70 vehicle and bus demonstrations around the world.[5]
- We have established a number of key partnerships between Canadian technology developers and automobile manufacturers from around the world.[6]

Mobile Applications: Choosing Short-term Priorities

Electrification of transport using fuel cells would drastically increase the amount of useful energy that actually propels the vehicles, given that energy losses within current ICE vehicles are huge—for every 100 units of energy expended in these vehicles, fewer than 10 units do useful work. This fact alone suggests that we consider the following opportunities.

Bus fleet demonstrations

Although buses make up less than 1 percent of the total number of vehicles operated in North America, their concentrated use in urban environments has a disproportionate impact on public health. Consequently, transit buses are one of the best applications for demonstrating alternative fuels and advanced technology systems in fleet-type applications. We can enhance our leadership in fuel cell technology by leading in fleet deployment of hydrogen-powered transit buses.

Canada demonstrated the first fuel cell buses in the world and is involved in a number of demonstrations currently underway abroad, including

- the European Union's Clean Urban Transport for Europe (CUTE) and Ecological City Transport System (ECTOS) programs, with 30 buses in 10 cities;

Ford Focus Fuel Cell Vehicle powered by Ballard's mark 902 fuel cell.

Source: Ballard Power Systems

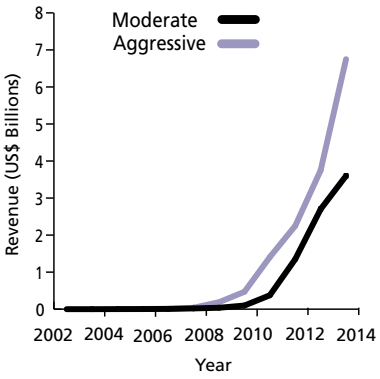


Figure 10. Automotive Fuel Cell Vehicles Sales Revenue World Market: 2002 - 2013

Source: ABI Research. © 2005. All rights reserved. Used by permission.

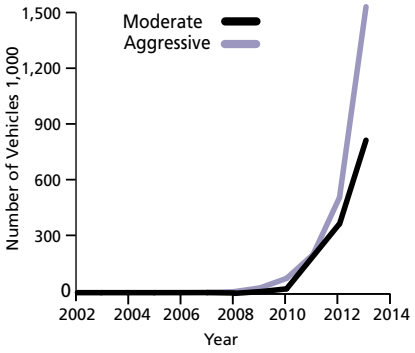


Figure 11. Automotive Fuel Cell Sales World Market: 2004 - 2013

Source: ABI Research. © 2005. All rights reserved. Used by permission.

Proposed BC Transit Fleet Demonstration

As part of the Hydrogen Highway™, BC Transit is championing the world's first hydrogen fuel cell bus fleet for an urban mass transit system. The proposal, to be implemented for the 2010 Winter Olympics, will operate a fleet of 15 – 20 buses in Victoria and Whistler.

- Western Australia's Sustainable Transport Energy for Perth (STEP) program, with 3 buses in Perth; and
- the United Nations Development Program/Global Environment Facility Fuel Cell Bus Program in Beijing

While these demonstrations are on a world scale, their focus is still limited to a maximum of three buses in any given location. Even so, this can help prepare the ground for later conversion of bus fleets to hydrogen power. In this connection, Canada could

- expand fleet sizes to test more vehicles and prove their feasibility in real-world operations;
- use high-profile activities, such as the Hydrogen Highway™ and the Vancouver 2010 Olympics, to demonstrate hydrogen-powered transit to the world; and
- use our experience in international mass transit demonstration projects to secure a role in expanded projects abroad and to export Canadian services.

Off-road utility vehicles

An early commercial market is emerging for off-road, hydrogen-powered utility vehicles such as forklift trucks and mining vehicles. These are already being tested in Canada and the US, and have potential in all major global markets.

Our best tactic may be to build on the ability of fuel cells to displace lead-acid batteries and internal combustion engines in specialized or dangerous environments, while providing increased efficiency, performance, safety and environmental protection.

Hydrogen-powered Internal Combustion Engines (ICEs)

Canada is currently developing blended-fuel technologies, such as hydrogen with diesel or CNG for use in trucks, buses and other mobile applications. Possible markets include the domestic automotive and fleet sector, as well as developing countries that are considering hydrogen ICEs as a bridging technology to fuel cell vehicles. Here we can

- take advantage of our technology to develop new capacities in hydrogen and blended-fuel engines;
- given India's and China's recent large fleet conversions to CNG and LPG, consider these countries as target markets for blended-fuel applications such as transit buses and light-duty trucks; and
- take advantage of early adoption of delivery vehicles that use hydrogen or blended-fuel ICEs.

Hybrid vehicles

Gasoline-electric hybrids could be another important transitional technology for establishing a mass market for fuel cell automobiles. Developments in the US and Japan are already highlighting this possibility, which could be a major transition opportunity for Canadian industry.

Canada could focus on building capacity in hybrid vehicle technology. This would allow us to gain experience with the lightweight materials, electric drive systems and battery technologies that the eventual commercial production of fuel cell vehicles will require.

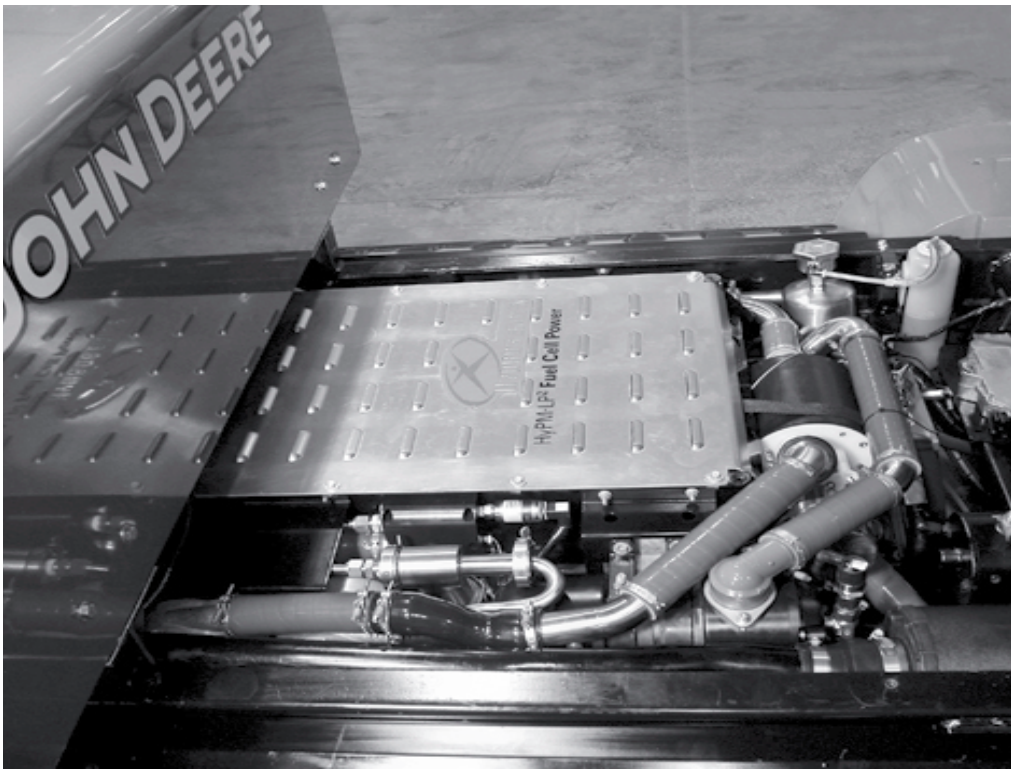
Mobile Applications: Questions for the Short Term

On which short-term opportunities we should focus to ensure that Canada can participate in future mass markets for hydrogen-powered vehicles?

How will we meet the cost and performance goals that are set by industry fuel cell commercialization roadmaps?

Should we align our targets with the US Department of Energy's performance goals or set our own national targets?

Should Canada explore partnership with China to jointly build and adopt the world's frst quarter million automobiles?



John Deere fuel cell demonstation work vehicle powered by Hydrogenics' HyPM power module

Source: Hydrogenics Corporation.

Parts production, standards and testing

The auto parts sector could develop new capability in the manufacture of auxiliary components for fuel cells, and in the development of improved materials for fuel cell stacks. Since few industry benchmarks or CSA/ISO standards exist for fuel cell components, we could also build expertise in standards development and testing for fuel cell materials. For example, we could

- establish a fuel cell component benchmark and testing facility to provide reliable third-party certification; and
- develop world expertise in the measurement and certification of hydrogen fuel quality and fuelling infrastructure operability.

Auxiliary power units (APUs)

APU systems currently use small gasoline ICEs to provide power, heat and air conditioning for large trucks independent of the vehicle's engine. Fuel cells could be used instead, improving efficiency and reducing emissions. Such APUs would also be useful in other transport applications, such as ships. In consequence, we could

- build on the early efforts of our companies to develop PEM and solid oxide fuel cell (SOFC) APUs; and
- make it a priority to explore domestic and export markets for these systems.

Mobile Applications: Choosing Medium- to Long-term Priorities

There are three important medium- and long-term possibilities for development in this sector.

Fuel cell vehicles

The commercialization of fuel cell vehicles, with associated fuelling infrastructures, is likely to take place on a global scale. The challenge for Canada will be to secure a position in this market in the face of competition from vehicles manufactured and purchased in other countries. Canadian fuel cell firms could develop stronger linkages or partnerships with automakers in the US, Germany, Japan and China and secure a mandate to jointly build and adopt the world's first quarter million fuel cell automobiles.

US Department of Energy (DOE) Performance Goals

In its multiyear R&D plan[7] the DOE set the following goals for an 80-kWe integrated fuel cell power system operating on direct hydrogen:

Durability ..... 5000 h

Survivability ..... freeze start capability to -40°C

Specific power* ..... 650 W/litre

Power density* ..... 650 W/litre

System cost* ..... US$45/kW (assuming 500 000 units per year

Assuming these performance goals are met by 2010, the DOE sees a commercial go or no-go decision by 2015 (in 2015, costs drop to $US30/kW).
*excluding H_2 storage

Hydrogen-powered bus fleets

Urban bus fleets are a key target for emission reduction. Assuming the success of our short-term demonstration projects, we could continue to develop advanced technology for hydrogen-fuelled buses that would emit zero or near-zero GHGs and air pollutants. Large-scale conversion of municipal transit bus fleets to fuel cells and blended-fuel ICEs could then be feasible.

Other mobile applications

As hydrogen vehicle markets and infrastructures grow, other applications such as rail, marine and air transport will convert to hydrogen power. In the long term, hydrogen fuel cell systems are expected to dominate in ground transportation systems and hydrogen APUs in flight applications. It would be useful to assess further opportunities in non-conventional markets such as rail, air and marine transport, with a focus on taking advantage of our current technological strengths.

Mobile Applications: Questions for the Medium and Long Term

Should we continue to target personal vehicles as the primary mass market for hydrogen and fuel cell technologies?

Will compressed gas storage provide sufficient range to meet customer requirements?

If so, how do we maintain Canada's position in this market as international automakers move to produce their own fuel cell systems?

To what other medium- and long-term mobile applications development could we dedicate our resources?

A Near-term Payback

Cellex Power's field trials have shown that, because of productivity gains and lower battery recharging requirements, consumers are willing to pay a premium to replace electric forklifts with vehicles powered by fuel cells.

The economic life of an electric lift truck is approximately 10 years, while the average rated life of an automotive lead-acid battery is about five years. The payback period for a fuel cell lift truck has been estimated at just over two years.

Cellex's CX-P150 fuel cell power unit powering a Crown class 3 rider-pallet truck in the order-picking application.

Source: Cellex Power Products.

Stationary Power

Hydrogen-powered fuel cells can be used in a variety of stationary applications, including

- off-grid and backup power;
- commercial and residential electricity and heating;
- distributed and centralized power generation; and
- remote industrial operations such as mining.

Canada has capacity in small stationary applications, but not in large ones such as centralized power plants. Some of the products nearing commercialization include backup power systems for server installations and telecommunications applications, as well as for distributed power generation.

Stationary Power: Our Strengths

We have several advantages in this sector:

- We are global leaders in commercializing small stationary PEM, Alkaline and SOFC products.
- We have the capability to develop technology for small residential, commercial and backup power applications.
- We are involved in 110 stationary power demonstrations worldwide and in more than 25 alliances with energy companies and international partners.

Stationary Power: Choosing Short-term Priorities

We have several short-term possibilities, ranging from off-grid power plants to large-scale power generation.

Off-grid power

One important application lies in small energy systems for remote areas off the electricity grid. In Canada and elsewhere, systems based on renewable energy can displace diesel generators, reducing energy costs, improving the environment and generating local jobs. We could

- use locally available renewable energy sources to demonstrate hydrogen-powered systems in remote communities; and
- take advantage of the rapidly increasing need for such applications in countries like China and India, as they seek to electrify remote or rural communities.

Residential power

The residential market in Japan is focused on small stationary power fuel cells for single-family homes. This market is expected to require a generating capacity of 10 000 MW by 2020 and could be a major opportunity.

Uninterrupted power supplies and backup power

Demands for environmentally preferable and more reliable, uninterrupted power supplies (UPS) and backup power are growing because of the needs of the financial, medical, communications and business sectors. There are numerous domestic possibilities, and we can also take advantage of current European and US interest in Canadian UPS and backup power solutions.

Distributed power generation

Distributed power generation relies on small, decentralized energy systems located where the energy is used. Hydrogen, produced locally from intermittent, renewable sources such as wind or solar energy, could fuel such systems. Using hydrogen to store the energy produced by these intermittent sources regulates the supply and makes the power more cost-competitive.

Developing countries that have intermittent energy sources are good candidates for distributed power. India's and China's rural electrification projects are an example.

Small-system demonstrations

There are opportunities to improve technologies and build markets by demonstrating scalable, stationary fuel cell systems in Canada and abroad. Domestic demonstrations of such systems are already underway for residential applications, UPS/backup power and cogeneration. These could be extended and followed up as we identify market possibilities.

Stationary Power: A Question for the Short Term

We could follow any of several possible directions in the area of stationary power applications. In the short term, the key question is to decide which ones would best position us to participate in future mass markets for stationary power.

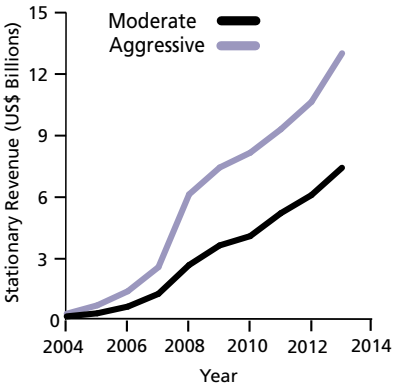


Figure 12. Stationary Fuel Cell Sales Revenue World Market: 2004 to 2013

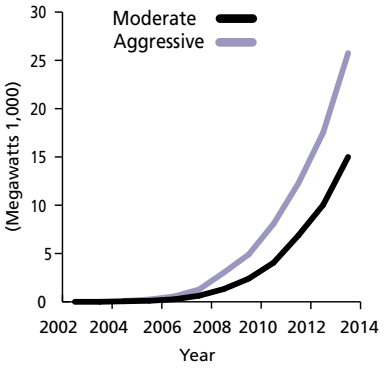


Figure 13. Stationary Fuel Cell Market Electrical Generation Capacity: 2004 to 2013

Potential for Remote Community Demonstrations

More than 2 million Canadians live in 310 remote communities, of which some 130 are off the grid. Fuel cells, deployed in homes, businesses and service buildings could replace diesel generators to create clean micro-grids for such communities.

Back up Power for Critical Applications

Mississauga-based Hydrogenics Corporation is providing 25 fuel cell power modules to the American Power Conversion Corporation, a leading global supplier of high-availability systems for network-critical physical infrastructure. Systems will be incorporated into backup power products to provide critical power applications that require reliable and extended-run capabilities.

High-Temperature Fuel Cells

The recently launched Energy Innovation Network (Energy INet), a growing national network of energy stakeholders, has shown a strong interest in exploring high-temperature fuel cell technology.

Designed to be an efficient, responsive link between today's energy challenges and the innovations of tomorrow, Energy INet is leading a process to build a Canadian Solid Oxide Fuel Cell (SOFC) Network, which will include universities, R&D institutes, government and industry. The Network will facilitate a strategic, collaborative and integrated approach to R&D for SOFC technologies in a way that will enable industry to take the technology to commercialization.

Large stationary power generation

Canada can build on its expertise with small stationary applications by developing new capacity in high-temperature fuel cells for large-scale power generation. We can also apply stationary systems to optimize the current electricity grid. Possible tactics include

- forming an international partnership to attract a high-temperature fuel cell manufacturer and enable technology transfer and manufacturing mandate to Canadian companies;
- investigating large cogeneration fuel cell systems in the US, which could be a key market opportunity for this technology; and
- through the federal government, fostering the development of the Canadian Solid Oxide Fuel Cell (SOFC) Network as proposed by Energy INet. This would allow us to investigate new opportunities in the commercialization of stationary power applications and develop new expertise based on our current knowledge of SOFCs.

Peak Shaving

Many industries cut their grid electricity usage during high-demand periods, a technique called "peak shaving." Hydrogen and fuel cell applications could provide solutions for companies that want to use this strategy to reduce their dependence on external power sources while energy costs are at their maximum.

Residential Cogeneration Systems

In February 2005, a partnership between Tokyo Gas and Ebara-Ballard Corp. launched the world's first residential fuel cell cogeneration systems in selected domestic markets in Japan. The systems will be available to 200 households by the end of fiscal 2005, with widespread use anticipated by fiscal 2008.

Source: Ballard Power Systems.

Stationary Power: Questions for the Medium and Long Term

Should Canada build expertise in large high temperature fuel cells for large-scale power generation?

Should Canada develop a plan for the deployment of stationary fuel cells in its remote communities?

Astris Model E8 Portable Generator for portable and backup power applications. Peak efficiency of more than 60%.

Source: Astris Energi Inc.

Portable Power

The global market for portable fuel cell systems grew by 75 percent in 2004. Canada is developing some expertise here, but the major Japanese, Taiwanese, Chinese and Korean manufacturers, because of their distribution channels and licensing arrangements, will likely lead in product diffusion to mass markets. Nevertheless, portable power devices and specialized applications can be a source of immediate funds to sustain the fuel cell industry during the next five to ten years. Canada also has an opportunity to partner with multinational enterprises in the personal electronics sector; these companies have high-volume production capacities and well-developed marketing and distribution networks.

Portable Power: Our Strengths

We have two chief strengths in this sector:

- We are actively developing capacity in micro fuel cells.
- We enjoy RD&D capability in early niche products, including auxiliary power units for portable applications, some of which have military use. The military is a potential early adopter for these applications and is willing to pay a premium for products that better meet their needs.

Portable Power: Choosing Short-term Priorities

Our two main opportunities follow from our existing strengths in this area.

Micro fuel cells

Japan has a strong lead in the production of fuel cells for portable consumer electronics. Direct methanol technology is being tested for these applications, as are other technologies including PEM, direct formic acid, electrolytes, silicon-based technology and new architectures such as mixed-reactant cells.

Our best tactic may be to build on the emerging capacity of Canadian companies to develop leading-edge technologies for these applications. Although high-volume manufacturing is likely to take place outside Canada, we could nevertheless play a role in the development and design of these technologies.

Military applications

Opportunities exist in military applications where portable battery packs and APUs are needed. They are a small market in terms of the numbers of units needed, but could be a large revenue generator.

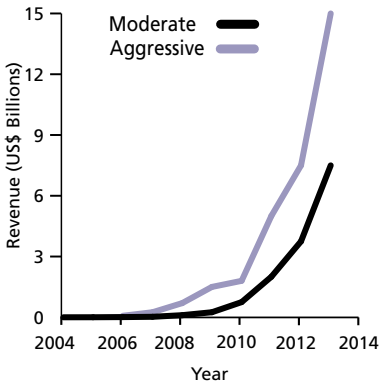


Figure 14. Micro Fuel Cell Revenue Forecast World Market: 2004 to 2013

Source: ABI Research. © 2005. All rights reserved. Used by permission.

Portable Power: A Question for the Short Term

The basic question that emerges from the above is whether Canada should, in fact, pursue the development of micro fuel cell applications?

Related to this is the question of how the hydrogen or other fuels would be supplied and stored for such cells if they came into widespread use.

The G2 module powers any electronic device with a USB power connector, including cell phones, PDAs, and digital cameras.

Source: Angstrom Power

The Global Market for Hydrogen & Fuel Cell Technology

United States

The United States is engaged in significant hydrogen and fuel cell demonstration projects, and constitutes Canada's largest and most accessible export market for this sector. The Canadian fuel cell and hydrogen industry, in fact, already receives almost 16 percent of its total revenue from the US market, and the US is also the location of 45 percent of the Canadian industry's RD&D activity.

The US market is driven by national objectives that include energy security and reliability, air quality, industrial development and wealth generation. Given Canada's already high level of market penetration, we are well positioned to participate in the next generation of US-based RD&D for these areas. Large fleet-focused programs and infrastructure projects, for example, represent significant revenue opportunities for the Canadian hydrogen and fuel cell industry.

Collaboration in building the North American new energy paradigm is already underway. In 2004, Canada and the US announced plans to expand technology partnerships to promote clean and efficient energy systems, and to support joint infrastructure projects through dedicated funding. In addition, the ongoing work of the International Partnership for the Hydrogen Economy (IPHE) and mechanisms such as the Security and Prosperity Partnership of North America (SPP) will help develop the regulatory frameworks needed for the commercialization of the North American hydrogen market.

Canada's Advantages

- Energy and automotive markets already integrated with those of the US
- Geographic proximity
- Complementary capacities
- Strategic alliances with OEMs

Market Opportunities

- Commercial automotive applications
- Mass transit buses, utility vehicles and APUs
- Military applications
- Fuelling infrastructure and hydrogen purification
- Large co-generation fuel cell systems

Policy Options

- Through new or existing demonstration programs, initiate additional joint Canada-US projects such as the West Coast Hydrogen Highway™.
- Establish a Canada-US PEM fuel cell R&D program.
- Engage OEMs and auto parts manufacturers in Canada.
- Attract investment in transitional technologies in Canada, such as electric and hybrid vehicles, hydrogen ICEs and blended natural gas/hydrogen vehicles.

European Union

The European Union represents about 16 percent of the world's energy market and imports about half the energy its member countries need. Gas and nuclear sources are replacing traditional oil- and coal-based energy generation. It is expected that CO_2 emissions will grow with increased gas use and that the EU will require major new initiatives to meet its GHG reduction goals under Kyoto.

In the EU, fuel cell and hydrogen R&D is driven by concerns about the environment, energy security and industrial competitiveness. Automotive and transport applications are the primary focus for EU fuel cell and hydrogen organizations. However, high electricity prices are also driving research aimed at integrating stationary fuel cell applications with renewable energy.

A continental approach to the development of a new energy paradigm is providing significant funding and collaborative leverage for country-specific programs. These EU hydrogen and fuel cell programs aim to support and complement national activities, promote public-private partnerships, and fund regulatory, educational and other hydrogen-related projects at a pan-European level.

Canada's Advantages

- Alignment with EU on codes and standards development
- Ability to build on large-scale demonstrations such as the Clean Urban Transport for Europe (CUTE) project
- Canadian links to Scandinavia and our similarities to Scandinavian countries with respect to geography and population
- Integration of hydrogen and fuel cell technology with renewable energy sources

Market Opportunities

- Residential fuel cell systems and UPS
- Fuel cell test equipment
- High-pressure hydrogen storage solutions
- Electrolytic hydrogen production, integrated with wind, solar and small hydro sources
- Fuel cell buses

Policy Options

- Continue to work in parallel with the International Energy Agency and the International Standards Organization to ensure market access to EU countries.
- Gather intelligence on EU strategies and frameworks.
- Carry out promotion and awareness campaigns and partnering activities in target countries such as the U.K., Germany and Scandinavia.

Japan

Japan, with its substantial population, large industrial base and lack of natural resources, is looking to hydrogen and fuel cells to reduce its dependence on the expensive and environmentally damaging fossil-fuel energy systems it now uses. Energy security and reliability, together with environmental protection and economic development, are the primary drivers of Japanese interest in the new energy paradigm.

Much of Japan's hydrogen and fuel cell R&D is funded through the Japan Automobile Research Institute, the Ministry of Economy, Trade and Industry, and the Japan Gas Association. A three-year budget of ¥30.7 billion (approximately C$316 million), proposed in 2003, would set a level of public investment exceeded only by that of the US. In the private sector, a variety of companies from the energy, machinery and chemical industries are also entering the fuel cell market.

In early 2005, Japan announced the first commercial release of residential stationary fuel cell technology, after an initial period of marketing the technology to telecom backup and data centers. In the transportation sector, the Japanese automotive industry is expected to leverage its market lead in hybrids during the next few years; in addition to this, the industry's target for 2010 is to have 50 000 fuel cell vehicles on Japanese roads. By 2012, demand from power suppliers, automobile companies, residential builders and electronics companies is expected to create fuel cell and hydrogen markets worth C$3.9 billion.

Canada's Advantages

- Japan and Canada have signed a new economic framework agreement called the Canada-Japan Economic Framework. This will include priorities such as broadening S&T, energy and climate change cooperation between the two countries.
- An existing record of partnerships with Canada and of foreign direct investment into Canada

- Participation in the development of codes and standards
- Integration of hydrogen and fuel cells with renewables and the potential for integration with nuclear energy

Market Opportunities

- Residential fuel cell systems
- Fuel cell test equipment
- High-pressure hydrogen storage technology
- Electrolytic hydrogen production
- Hydrogen purification
- Liquid hydrogen supply
- Fuelling infrastructure
- Safety codes and standards

Policy Options

- Explore opportunities for increased foreign direct investment into Canada, together with opportunities related to the integration of renewable, nuclear, and hydrogen energy resources.
- Transfer knowledge of codes and standards to Japan.
- Share fuelling station knowledge and expertise with Japan.

Emerging Markets

In developing countries, rapid economic growth is driving a phenomenal demand for energy. China and India in particular will have a major influence on the hydrogen and fuel cell industry as their expanding technical and manufacturing capacity exerts an ever-increasing effect on global supply chains.

These countries present tremendous market potential, including the opportunity for new technologies to leapfrog conventional ones. The near-term sharing of technologies and the development of new partnerships will encourage successful commercialization in Canada and promote long-term market penetration abroad.

China

China urgently needs energy and natural resources to support its growth. The drivers for China's fuel cell and hydrogen R&D are concerns about energy supply, distribution and security, together with problems of air quality and the desire for manufacturing leadership.

China considers fuel cells and hydrogen as central to its long-term science and technology development strategy. To date, China has invested approximately C$2.8 billion in fuel cell and infrastructure RD&D. These activities have focused on portable, stationary and mobile applications, and on the production of hydrogen from solar, biomass, natural gas and coal resources.

Canada's Advantages

- Sharing of knowledge and expertise
- Current Canadian natural gas sector activities in China
- Early mass-market opportunities allowing a "leapfrog" approach
- Canadian hydrogen technology knowledge that can be leveraged to develop manufacturing expertise
- Leadership in fuel cell bus demonstrations

Market Opportunities

- Hydrogen production technologies from clean coal
- Hydrogen storage using solid-state and high-pressure technologies
- Distributed power generation
- Fuelling infrastructure and hydrogen purification
- Fuel cell buses and small motorbikes
- Fuel cell stacks and systems
- Electrolytic hydrogen production
- Manufacturing for large order of fuel cell automobiles
- Turn-key solutions

Policy Options

- Establish a framework to address intellectual property (IP) issues, such as a Foreign Investment Promotion and Protection Agreement (FIPA) with China, or IP agreements facilitated by government-to-government negotiations
- Continue to participate in bilateral and multilateral negotiations to ensure appropriate future market access
- Support the National Research Council's workshops and activities on codes and standards
- Provide full-system solutions based on Canadian leadership through consortium approaches
- Support Canadian consortium approaches such as the Canada-China Hydrogen and Fuel Cell Coalition

India

India is the world's second-most populous country, with a huge and rapidly growing middle class and a booming economy. Reforms and deregulation in the 1990s have led to an improved investment climate and an increased competitive position for Indian industry.

Drivers for the transition to the new energy paradigm are air quality concerns, rural electrification, energy security and reliability, and energy demand.

In a country where transportation accounts for nearly half the energy consumption, fuel cells and hydrogen technologies are seen as a way to improve the air quality in India's heavily polluted cities. India is interested in adopting hydrogen/CNG mixes for use in rickshaws, buses and trucks, and in developing hydrogen ICEs. Two million rickshaws have recently been converted to CNG and in Delhi, the world's most polluted city, buses have already been ordered to convert to natural gas.

Canada's Advantages

- Sharing of knowledge and expertise
- Current Canadian natural gas sector activities in India
- Early mass-market opportunities allowing a "leapfrog" approach
- Expertise in electrolysis systems and in hydrogen and blended-hydrogen ICEs
- Joint agreement to enhance S&T and energy cooperation between Canada and India

Market Opportunities

- Hydrogen/CNG blends for ICEs in buses, trucks and small vehicles
- Distributed power generation
- Electrolytic hydrogen production from solar and biomass sources
- Fuelling infrastructures and hydrogen purification
- UPS full-system solutions in the information technology sector
- Turn-key power solutions

Policy Options

- Negotiate Memoranda of Understanding among research organizations and governments, specifically around ICEs using hydrogen and hydrogen blends.
- Promote awareness of Canadian capacity and technology by increasing our presence through fact-finding missions, conferences and other events.
- Develop intellectual property policies to protect Canadian leadership and facilitate alliances with Canada.

Refueling the John Deere fuel cell vehicle at a Hydrogen Gas Dispenser

Source: Hydrogenics Corporation.

Building Industry Strength

Once implemented, the Canadian National Hydrogen and Fuel Cell Strategy will focus on developing an energy industry that will ultimately provide a long-term, sustainable energy solution for Canada and the world. This part of the Discussion Document describes numerous short-term actions we can carry out to take advantage of the opportunities identified in the preceding sections, as well as help us address priority issues. These possible actions, which include tools, policies and initiatives, could be applied in the following critical areas: research and development; demonstration and deployment; education, awareness and outreach; regulation; and coordination, analysis and promotion.

The Discussion Document does not seek to hand down preconceived solutions, but rather to formulate questions whose answers may help us frame the strategy and action plan in a realistic way. It is intended to identify and prioritize opportunities, to engage all stakeholders in a concerted effort to address the needs of the sector, and to select the most effective short-term actions that stakeholder groups can undertake to meet Canada's overall objectives for the sector.

Pursuing Immediate and Near-term Opportunities

Canadian companies that gain early market share will be the most likely to acquire a lead in technological and production capacity. This will better position them to secure mid- to late-market opportunities. Some possibilities for building this early capacity and revenue stream, and thus a sustainable Canadian industry, are as follows:

- We can seek opportunities to generate greater revenues through increased participation in RD&D (Research, Development and Deployment) markets worldwide. Our international reputation for quality and expertise, together with a network of partnerships, would help ensure our position in the next generation of these markets. We should not delay in this, however, since competition in RD&D markets is increasing as other countries build their capabilities.
- Many major markets, including Japan and the US, have set technology and performance targets according to their particular economic, energy and environmental priorities. Canadian companies, especially those in partnership with firms in such markets, could align their domestic RD&D with these targets. This could increase both our participation in foreign RD&D and

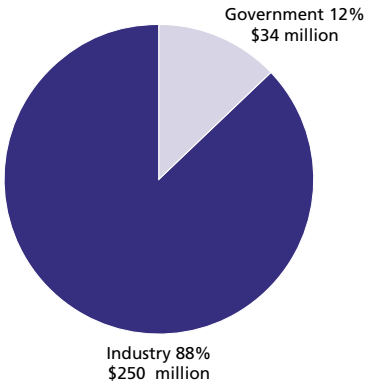


Figure 15. Fuel Cell R&D Investments in Canada, 2003

Source: Canadian Hydrogen and Fuel Cell Sector Profile 2004, Government of Canada, Fuel Cells Canada, PricewaterhouseCoopers.

our revenues from it.

- We can set our own national technology performance and adoption targets and priorities on the basis of the applications to be developed.
- We will complete and expand current, large-scale demonstration projects and create more such projects in this country.
- We can focus on generating revenue from existing niche markets such as those described in the previous sections—light industrial vehicles and portable and mobile applications, for example.

Creating a Balanced Approach to Research, Development and Deployment

Canada currently plays a prominent role in the global fuel cell industry. However, as the industry evolves, the technology pioneered in this country may diminish in value. If we are to maintain our leadership, we need to decide what level of R&D investment, and in which key areas, will achieve our goals to reduce the cost of the technology and increase its performance. Industry, government and academia should continue to collaborate on applied development, pre-commercialization and the basic research needed for scientific breakthroughs.

Advancing the hydrogen and fuel cell sector will require us to progress through various stages of industry development, including

- basic R&D;
- applied R&D and product development;
- engineering and testing;
- development of codes and standards;
- technology demonstrations;
- market demonstration;
- fleet deployment; and
- production and sales.

Different technologies within the sector are now at different stages of the commercialization process. Difficulties at any of these stages can slow overall progress, but support for commercializing niche applications will help solve technical and market problems, build hydrogen fuelling infrastructures and accelerate the full-scale commercialization of automotive applications. To date, the Canadian hydrogen and fuel cell industry has played a prominent role in R&D in Canada. Universities and government labs interact and collaborate with companies on specific projects, but there is currently no concerted national R&D strategy for the sector. As the sector evolves, there is a growing need for increased momentum on R&D both at the company and pre-commercial levels. Collaborative research, particularly of the fundamental type, to address critical technology breakthroughs is required to reach commercial viability. This calls for an appropriate R&D model that will foster a more focused and coordinated approach to R&D on a national basis. Such a model is necessary for Canada to compete globally, and to harness the full potential of academic and public research organizations in assisting the industry.

A more centrally directed RD&D strategy could also ensure that public funding balances the needs of both fundamental and applied research. This would involve support for direct industry research and would also address issues of capability and technology transfer so that academics and public organizations play a key role in the basic research needed for scientific breakthroughs. It would also ensure that government is able to support industry to perform its own proprietary product R&D while ensuring that basic R&D is linked to future industry needs. This could accelerate industry's progress toward the technology breakthroughs necessary for the full-scale commercialization of hydrogen and fuel cell technologies.

Possible Actions

Identify the critical challenges for R&D in the coming five years including identifying resource requirements, partners and mechanisms for delivery. The results of this analysis will be incorporated as a key element in the National Strategy.

Develop and implement a national coordinated R&D strategy for hydrogen and fuel cell technologies. This strategy would address two key issues: focusing on critical R&D challenges for companies and fostering a more coordinated approach to hydrogen

and fuel cell R&D in Canada. A proposed new model would emphasize a sharper focus on critical R&D challenges and technology gaps faced by the industry in Canada, and the optimal means to tackle them. To this end, a consortium-based approach is suggested for each key area of the sector in Canada. Various organizations may assume a leading role in coordinating each of these focused R&D networks, as deemed suitable by its participants. One such initiative centered on SOFC technology is already being undertaken. The creation of similar networks for PEM fuel cells and hydrogen technologies could be another option.

Possible Action

Establish a Canadian Network of Centres of Excellence for Hydrogen and Fuel Cells, focused on all aspects of commercializing hydrogen and fuel cell technologies. Priorities would include pre-commercial and fundamental research related to materials sciences, advancements in membranes and catalysts, and hydrogen production and storage technologies.

Building the North American Hydrogen Economy

The Canadian and US governments are currently exploring areas and mechanisms for greater collaboration in hydrogen and fuel cell RD&D. The intent is to build both countries' competitive advantage in the global hydrogen and fuel cell sector, and to ensure that both nations reap the benefits of North America's transition to a continental new energy paradigm. This initiative is very important to Canada; while our industry investment in RD&D exceeds $200 million annually, this alone cannot maintain Canada's competitive advantage.

Collaboration also supports Canada's commitment to the North American Security and Prosperity Partnership (SPP), and hydrogen is a priority under the Energy Working Group. A US-Canada R&D collaboration would underpin the development of a common regulatory framework and a continent-wide hydrogen infrastructure, contribute to our technology and commercialization objectives, and be an excellent way to raise consumer awareness of hydrogen-based energy systems.

Possible Action

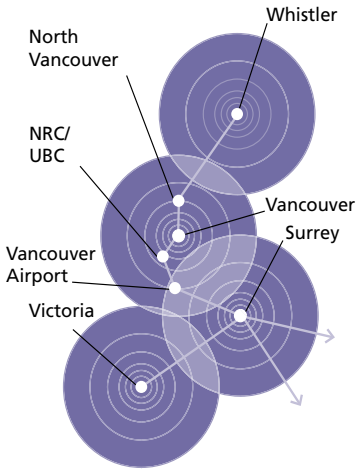
Propose a Canadian solicitation for PEM R&D to parallel the United States' US$100 million solicitation. The common objective would be to develop breakthrough technologies to commercialize fuel cell systems for transportation and stationary applications. The solicitation would focus on the issues of cost, performance, reliability, durability and safety that must be addressed before we can achieve our objectives. It would propose teaming and cost-sharing partnerships among industry, universities and research organizations to support the necessary R&D. This initiative would be the first step in building an R&D framework for constructing the North American new energy paradigm.

Establishing a Coordinated Approach to Canadian Hydrogen and Fuel Cell Innovation Programming

A coordinated approach to innovation programming would allow government agencies, commercial developers, national research organizations and universities to work together toward a common goal: to bring clean, affordable and efficient hydrogen technologies to market within 10 years. Such a program could

- perform targeted R&D to lower the cost of hydrogen and fuel cell technology and improve its performance;
- demonstrate the viability of hydrogen infrastructure technology, including production, distribution and storage, as well as portable, stationary and mobile applications;
- address the current commercialization gap in this country;
- serve as an excellent model for joint public and private approaches to technology R&D;
- provide an effective use of R&D capital investments to reach technology breakthroughs and accelerate the transition to the new energy paradigm;
- encourage entrepreneurship in the hydrogen and fuel cell sector; and
- support analytical efforts in modeling the new energy paradigm.

Government funding is increasing, but complex administrative procedures have sometimes made funds difficult to obtain.



British Columbia, Canada

The Western Hydrogen Highway™ Network, linking British Columbia to Southern California.

Source. HYDROGEN HIGHWAY™ is a trade-mark of Fuel Cells Canada. Fuel Cells Canada gratefully acknowledges the donation of this trade-mark by B.C. Hydro, Methanex and the National Research Council of Canada.

Government and Industry Partnerships

The Greater Toronto Hydrogen Village™, the BC Hydrogen Highway™ and the Vancouver Fuel Cell Vehicle Program are being built by partnerships that include the Government of Canada, Technology Partnerships Canada, Hydrogen Early Adopters program, the Canadian Transportation Fuel Cell Alliance, the Ontario Fuel Cell Innovation Program, Sustainable Development Technologies Canada and the BC Hydrogen and Fuel Cell Strategy.

Such barriers can prevent companies from responding quickly to emerging niche-market opportunities. A coordinated funding support process would alleviate this problem and help increase company participation in growing RD&D markets.

Possible Action

Investigate the possibility of streamlining the funding support process to establish a coordinated approach and accountability framework for hydrogen programs. The framework would focus on the RD&D and commercialization priorities outlined in the National Strategy, and would coordinate and simplify the application process for support for these priorities. Investments in federal hydrogen and fuel cell programs that have a high level of efficiency could also be increased.

Possible Actions

Through open-minded, creative brainstorming by small groups of industry and program managers, outline industry issues and government constraints to suggest realistic and workable solutions.

Establish a biannual or annual "company information blitz" where companies can meet with program managers and present their work plans, projects and needs.

Possible Action

Establish a Hydrogen and Fuel Cell Alliance focused on all aspects of commercializing hydrogen and fuel cell technologies. It would take technology right from R&D to demonstration, linking universities, research organizations and government with industry. R&D priorities would include catalysis, membranes, materials and modeling for hydrogen production, storage and fuel cells. Successful technologies would be taken from lab scale to demonstration and deployment.

Increasing Access to Capital

Because of the long timelines for commercializing hydrogen technology, the industry needs sustained and stable financing if it is to realize the medium- to long-term opportunities offered by hydrogen and fuel cells.

Raising enough capital to sustain high levels of R&D has always been a major concern for the small companies that make up most of the industry. Fortunately, they have so far been very successful in garnering support from government sources, large multinational original equipment manufacturers (OEMs) and public equity markets. But obtaining capital is becoming steadily more difficult.

Creating Innovative Market Framework Policies

While government will play a central role in supporting and coordinating industry-wide research and the allocation of public funds, private funding will remain essential. Canadian industry's success will hinge on its ability to raise investment capital for the R&D required to achieve technological breakthroughs. However, although Canadian firms have been successful in accessing capital from private and public markets and can provide sources of equity, long commercialization timelines could mean that some firms may find it more challenging to secure private funds in the future.

The industry has projected that it will need $1 billion in capital during the next decade to carry out the R&D that will lead to commercialization. The government will work with industry to review existing public supports to ensure that they enable the industry to access the capital it needs to maintain R&D momentum, promote early adoption and foster the early commercialization of the technologies.

Possible Action

Examine the Government of Canada's current programs and policies, and determine whether they need to be revised to meet the needs of the hydrogen and fuel cell sector more effectively.

Expanding Current Demonstration Programs to Draw Investment

High-profile demonstration projects and a realistic public awareness campaign—one that presents a balanced view of the industry—are essential to increasing investment and eventually driving market demand.

Possible Action

Increase investments in current federal hydrogen and fuel cell programs to support learning demonstrations, as well as fundamental and advanced RD&D, in Canada and abroad. This would advance the commercialization of Canadian technologies.

Developing Capabilities and Fostering Market Adoption

Strong industry clusters consisting of complementary organizations are the foundation of the value chain. They not only streamline the development and delivery of expertise and products, but also attract alliances with, and investment from, large multinational organizations interested in outsourcing research and manufacturing. Expanding these clusters will be vital if Canadian industry is to meet the needs of its evolving markets.

Building the Supply Chain

Traditionally, R&D investments from large OEMs have been a major source of revenue for the industry. However, this market is changing quickly. While Canadian companies have often been partners in developing basic technology, many OEMs are now developing the in-house ability to refine this technology and integrate it into their product lines. Canadian companies may need to decide whether relationships of this type are in their best interests and, if necessary, identify other opportunities that will better reward their efforts.

Possible Actions

Engage other sectors in developing early capacity for integrating fuel cells into market applications.

Analyze future manufacturing requirements for mass production of hydrogen and fuel cells.

Support the implementation of a Sustainability Network of Centres of Excellence to bring together the various players from the energy, manufacturing and policy sectors.

Engage the automotive and auto parts sector in developing early production capacity for the fuel cell sector and for mobile technologies such as hybrid vehicles.

We also can analyze Canada's existing fuel cell and hydrogen industry clusters to identify gaps in resources and capacity that will affect existing and future market demands.

Possible Actions

Establish a formal consultative mechanism between industry and government through Canada's Hydrogen and Fuel Cell Committee. This would address critical issues on a yearly basis and encourage effective communication among all parties.

Continue to analyze Canada's existing fuel cell and hydrogen industry clusters to identify gaps in resources and capacity, relative to current and future market demands.

Begin a performance benchmarking report to address industry progress and associated government investment.

We may also require a new way of thinking that will place a monetary value on the costs and benefits, both social and environmental, of using hydrogen technology.

Possible Action

Work with industry to provide a quantitative comparison of hydrogen technology costs and benefits versus those of incumbent technologies. Use these analyses to show that the cost of hydrogen technology, relative to incumbent technologies, is not as high as the current market price suggests, because the market price does not factor in the social and environmental costs of the incumbent technologies.

Capturing Early Market Opportunities

Taking advantage of immediate and near-term markets is essential for developing robust technologies and lowering their costs, as well as for developing world hydrogen infrastructure. There are gaps in our ability to do this, and we need strategies to close them.

The Canadian government can play a unique part here by becoming a "first user" of these early market applications. This would help the industry build capacity, encourage the use of the technology and demonstrate its marketability to international buyers.

Possible Action

Undertake regional outreach measures, including workshops, where various stakeholders can meet to identify specific ways and projects that will encourage the adoption of hydrogen and fuel cell systems.

Possible Action

Under a "First Purchase Program," select industrial users and Canadian governments and their agencies could become "first purchasers" of hydrogen, fuel cell and other emerging energy technologies. By giving purchase preference to Canadian-developed technologies in an early commercial stage, these users could provide leadership and incentives for other public and private organizations, as well as for consumers, to adopt these technologies

Canada also has a unique opportunity to work with emerging markets to develop technologies that match their growing energy demands and dispersed infrastructures.

Possible Actions

Continue to work with the Emerging Markets Initiative, led by International Trade Canada, to take advantage of opportunities offered by these markets. This would concentrate on developing and deploying best-in-class technologies to achieve mass commercialization of hydrogen and fuel cell technologies.

Provide support for developing countries and their companies so that they can attend Canadian missions and partnering events.

Branding the Canadian Industry

A well-branded Canadian industry would help support the marketing efforts of our companies by concentrating on "Made in Canada" solutions that reflect our social, environmental and economic priorities. Such branding could build on our contribution to making a global new energy paradigm possible and on the cooperative relationships among industries and governments in the international community.

Possible Actions

Continue to support a strong Canadian presence at international conferences and trade shows by using the Canada Pavilion to present Canada's strengths and strategies in the sector.

Encourage high-level support from key ministries within the federal government, and facilitate this by developing a consistent ministerial message that can be delivered at major international events.

Provide financial and in-kind support to Canadian industry for initiatives that promote Canadian solutions abroad, such as the Canada/China Hydrogen & Fuel Cell Coalition.

We also have a unique opportunity to use major venues such as the 2010 Olympics and the World Urban Forum to brand Canada as a world leader in hydrogen and fuel cell RD&D. For example, the 2010 Winter Olympics and Paralympics would provide a showcase for these state-of-the art technologies.

Possible Action

Propose an investment and partnership with BC Transit to support the demonstration of a fleet of 15 to 20 fuel cell buses, to be showcased during the 2010 Winter Olympics and beyond.

Finally, an internationally recognized role in establishing testing and benchmarking systems would validate Canadian assurances of quality and contribute to the strength of the "Made in Canada" brand.

Possible Action

Foster more links among the federal government and industry, academia and private research organizations to establish world-class benchmarks, diagnostics and testing facilities. This would build on current Canadian capacity including the NRC Institute for Fuel Cell Innovation, the Hydrogen Research Institute, AUTO21 and the Centre for Automotive Materials and Manufacturing.

Attracting Anchor Companies and OEMs to Canada

The benefits of establishing operations in Canada should continue to be promoted. Canada offers an excellent location for innovation and investment, a stable competitive financial sector and a world-class communication, technology and transportation infrastructure. We have a highly skilled workforce and qualified business leaders. Our low inflation, low interest rates and competitive tax system allow many Canadian cities to offer some of the lowest start-up and operating costs in North America.

Possible Actions

Use ministerial and other high-level visits abroad to promote Canada as a location of choice for investors.

Develop a promotional video to highlight the benefits of establishing operations in Canada and to show the strengths of our hydrogen and fuel cell clusters.

CAN-TRADE

A Government five-year $470 million Action Plan will help secure Canada's future prosperity by intensifying business community engagement in the rapidly changing global economy.

Developing Skills, Education and Awareness

Much of Canada's leadership in this industry is due to our impressive concentration of expertise. To maintain this advantage, we will need to educate new generations of scientists, scholars and other knowledge workers.

Encouraging Skills Development

Skilled technical personnel will be required to support demonstration projects and expand applied research and product development. As the market grows, so will our need to train expert production, service and support workers. We therefore need to identify and address the gaps in our capacity to achieve this level of training.

One approach could be to better align the Canadian transportation and energy sectors with our post-secondary institutions and trade schools. This could include

- company training programs to meet immediate needs;
- demonstration projects or early purchases that incorporate training components;
- information programs for career opportunities;
- a nationally accepted certificate for hydrogen and fuel cell tradespeople;
- more courses and programs at selected universities and technical schools; and
- expanded co-op/internship programs at hydrogen and fuel cell technology companies.

Fortunately, educational organizations are becoming increasingly interested in incorporating hydrogen and fuel cell research into their curricula, and some institutions are already offering extensive formal training. At the graduate level, students are learning from a growing body of researchers; the National Research Council and Natural Sciences Engineering Research Council, (NRC/NSERC), for example, support a fuel cell chair and graduate fellowship programs in Canadian universities.

We can also place more emphasis on recruiting senior industry executives. We will need these people to help Canadian companies compete in international RD&D markets and to provide the leadership that will secure our position in future markets. In addition, we need world-class researchers to make the breakthroughs that will sustain the demand for our technology and overcome the technical barriers to commercialization.

In short, by taking advantage of our prominence in the hydrogen and fuel cell industry, Canada could become an international centre for hydrogen and fuel cell education.

Possible Actions

Build on the British Columbia's Knowledge Special Interest Group's initiatives to develop specialized post-secondary and technical school curricula through Human Resources and Skills Development Canada (HRSDC) sector tables.

Use Research Chairs to foster the recruitment of key management and research individuals who have the skills we need.

Encouraging Public Education and Awareness

The shift to a hydrogen-based economy will have profound effects on the lives of Canadians. To ease the transition, we will need to ensure that our communications garner support and acceptance for these new technologies, not only from stakeholders but also from the public. In particular, public understanding that this technology is economical, safe, efficient and environmentally sound is crucial to moving hydrogen and fuel cells rapidly into the marketplace.

It will be crucial for all stakeholders to work together to ensure that this information is effectively communicated. To do so, we can build our message into new and existing information activities and products related to hydrogen safety, consumer acceptance, economic potential and education and skills development.

For example, Fuel Cells Canada and the federal and provincial governments are working together to create Canada's first Hydrogen and Fuel Cell Technology Demonstration Centre. It would be

located at the new Institute for Fuel Cell Innovation, which is to open in spring 2006. Intended to play a unique role in showcasing demonstration projects as well as Canadian products and technology, the Centre would increase public awareness of Canada's research capabilities and will educate government, the media and visitors about Canada's leadership and expertise in hydrogen and fuel cell technologies.

Possible Actions

Increase funding for programs to encourage the kinds of behavioural change that will lead to widespread adoption of hydrogen and fuel cell technologies.

Leverage the success of existing demonstration projects to enhance public awareness and acceptance.

Develop and implement major campaigns that target regulators, governments, early adopters and the public to raise awareness of the benefits of hydrogen and fuel cell technologies.

Build Canada's first Hydrogen and Fuel Cell Demonstration Centre at the new National Research Council's Institute for Fuel Cell Innovation, which is to open in spring 2006.

Build on proven campaigns to ensure that our messages are consistent and that the overall mandate of the government is being met.

Ensure that communications are aligned with provincial and municipal strategies and, where possible, cooperate with these groups to develop common messages.

Track public perception of hydrogen technologies through more frequent public opinion polls.

Continue to work through the International Partnership for the Hydrogen Economy to develop educational materials and increase the awareness of hydrogen and fuel cell technology.

Increase awareness among children at primary and secondary schools, using models such as the Schools on Board program of ArcticNet, which is based out of the Faculty of Environment at the University of Manitoba.

Implement a series of national and international workshops that will help us better understand how social policy development and governance structures will relate to the transition to the new energy paradigm.

Developing Codes and Standards

Canada has taken a proactive approach to the development of hydrogen codes and standards (C&S). Through the Bureau de normalization du Québec (BNQ), Canada has supported ISO TC 197 to develop C&S for hydrogen technologies. Currently, hydrogen stakeholders are working with the BNQ to develop a Canadian Hydrogen Installation Code, which will be the basis of a Canadian national code. BNQ, using its position as the secretariat for ISO TC 197, will move this document to the international arena by proposing it for adoption as an ISO standard.

In September 2004, the Government of Canada conducted a Hydrogen and Fuel Cells Codes and Standards Workshop to begin a discussion of regulations needed in Canada. A White Paper is currently being developed by industry that will identify current and future needs, and present a plan for the orderly development of C&S. The workshop also provided an opportunity for participants to become involved with the National Public Safety Advisory Committee (NPSAC), a provincial/territorial/national body that represents all Canadian jurisdictions, and which can provide a strong voice on public safety issues.

NPSAC is developing a process to streamline the adoption of common regulations across Canada. Hydrogen has been chosen as the model case, and British Columbia has taken the lead in moving the initiative forward. This will encourage the common adoption of hydrogen C&S by regulators at the provincial and territorial levels.

The Canadian Transportation Fuel Cell Alliance (CTFCA) Codes and Standards Working Group is also active in this area. The CTFCA integrates the interests of industry, governments and standards development organizations in developing C&S, and the Working Group has become the lead body for hydrogen C&S development for federal

hydrogen programs. Transport Canada is an active participant in the Working Group, addressing industry concerns such as vehicle safety and the transportation of hydrogen from where it is produced to where it is used.

Possible Action

Continue to work with the Canadian hydrogen stakeholder community to build national C&S in both an international and a North American perspective, and streamline and increase our efficiency in adopting C&S.

Canada's industrial leadership will also allow us to play a major role in the development of the benchmarking specifications, methodologies and evaluation protocols that are the foundation of regulatory compliance.

International venues such as the International Partnership for the Hydrogen Economy and the Working Groups of the International Energy Agency provide essential mechanisms for sharing C&S knowledge and progress with other countries. The Canadian Hydrogen Safety Program of the CTFCA is an integral part of Canada's input to Task 19, "Hydrogen Safety," of the IEA Hydrogen Implementing Agreement.

Possible Action

Continue to support multilateral mechanisms that address the consistency of international codes and standards, and share information that will underpin the development of these codes and standards.

The National Research Council Institute for Fuel Cell Innovation has world-class facilities and researchers focused on fuel cell research and development.

Canadian Governments: Partners for the Hydrogen Future

While all Canadians will participate in the shift to a new energy paradigm, Canadian governments at all levels have an initial, catalytic role to play in the transition. As partners in this process, they can commit themselves to using environmentally preferable energy sources and new technologies, thus spurring commercialization and confronting concerns about energy diversity, energy security and environmental protection.

Governments, in fact, have many strengths and capabilities that would help them form vibrant and fruitful partnerships with industry, academia and the research community. Educational initiatives, government-backed communications and awareness programs, collaboration in demonstration projects, tax and financial incentives and innovative environmental policies are only a few of the ways that governments can support the partnerships that will speed the transition to a new energy paradigm.

Developing a National Hydrogen and Fuel Cell Strategy is crucial to understanding how hydrogen technology can contribute to a future of clean energy for Canada and the world, and how governments and stakeholders can become partners in bringing this about. This Discussion Document, by setting out a vision and the key questions and options associated with it, is intended to stimulate constructive debate about the vision itself, and about our goals and the means we can use to reach them.

The Discussion Document also emphasizes that a dedicated and strategic effort by governments, in partnership with the research community and industry, is both possible and feasible. It also assumes that the vision it articulates is ultimately a realistic one and that it is within our power to achieve it. The potential benefits of doing so, from energy security to economic growth to environmental protection, are almost incalculable. Canada, to its good fortune, has a unique opportunity to lead the world in this enormous and historic transformation.

Next steps

This document represents the second step in a seven-step process of preparing and initiating a National Hydrogen and Fuel Cell Strategy. The overall process is envisioned as the following:

Step 1

Establish the initial direction and priorities for the strategy.

Step 2

Undertake the development of a Discussion Document and carry out early consultations with key stakeholders and experts.

Step 3

Engage in a broader consultation process.

Step 4

Finalize the National Hydrogen and Fuel Cell Strategy.

Step 5

Obtain Cabinet approval of the National Hydrogen and Fuel Cell Strategy and its proposed priorities.

Step 6

Release the National Hydrogen and Fuel Cell Strategy.

Step 7

Implement the National Hydrogen and Fuel Cell Strategy's recommendations and monitor progress.

Working Notes

A Vision for Canada

Is this the right vision for Canada?

What should Canada's adoption targets be in:

- number of pre-commercial and commercial units in mobile, stationary, portable applications and hydrogen stations?
- percentage of installed power?
- percentage of energy production?

Canada's Opportunities in the Global Hydrogen Future

- Which existing Canadian hydrogen and fuel cell technologies or applications hold the most short-term promise, and in which markets?
- Which mid- and long-term technologies, applications and R&D priorities are needed to build a sustainable hydrogen and fuel cell industry?
- How can Canadian technology and applications align better with our major export markets over both the short and long terms?

Hydrogen Infrastructure

Questions for the Short Term

Should Canada continue to pursue all pathways for hydrogen production, or specialize in a smaller number of carefully selected ones?

What supporting technologies, such as CO_2 capture and storage, could we co-develop for our chosen pathways?

Once the pathways are selected, which opportunities and tactics will allow us to build production, delivery and storage infrastructures for them?

Once the pathways are selected, how do we establish Canada in the export markets related to them?

Could the expansion of large-scale hydrogen production for oil sands provide infrastructure for fuel cell deployment and early adoption?

Questions for the Medium and Long Term

Which opportunities will encourage the rational development of hydrogen infrastructure?

What resources should we devote now to these opportunities?

To what extent could new primary energy resources for hydrogen production, such as biomass and biological methods, be developed on a regional basis to meet economic and emission objectives?

Should the research community be engaged to develop low pressure hydrogen strorage technologies?

Mobile Applications

Questions for the Short Term

On which short-term opportunities we should focus to ensure that Canada can participate in future mass markets for hydrogen-powered vehicles?

How will we meet the cost and performance goals that are set by industry fuel cell commercialization roadmaps?

Should we align our targets with the US Department of Energy's performance goals or set our own national targets?

Should Canada explore partnership with China to jointly build and adopt the world's frst quarter million automobiles?

Questions for the Medium and Long Term

Should we continue to target personal vehicles as the primary mass market for hydrogen and fuel cell technologies?

Will compressed gas storage provide sufficient range to meet customer requirements?

If so, how do we maintain Canada's position in this market as international automakers move to produce their own fuel cell systems?

To what other medium- and long-term mobile applications development could we dedicate our resources?

Stationary Power

A Question for the Short Term

We could follow any of several possible directions in the area of stationary power applications. In the short term, the key question is to decide which ones would best position us to participate in early market niches and future mass markets for stationary power.

Questions for the Medium and Long Term

Should Canada build expertise in large high temperature fuel cells for large-scale power generation?

Should Canada develop a plan for the deployment of stationary fuel cells in its remote communities?

Portable Power

A Question for the Short Term

The basic question that emerges from the above is whether Canada should, in fact, pursue the development of micro fuel cell applications?

Related to this is the question of how the hydrogen or other fuels would be supplied and stored for such cells if they came into widespread use.

Global Markets

Which geographic markets should Canada be focusing on for:

1) Mobile Applications

2) Stationary Applications

3) Portable Applications

4) Infrastructure

5) Joint R&D Activity

Building Industry Strength

Identify key priorities for:

1) Creating a balanced approach to R&DD

2) Developing capabilities and fostering market adoption

3) Developing skills, education and awareness

4) Developing codes and standards.

End Notes

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5. Ibid.
6. Ibid.
7. US Department of Energy. Hydrogen, Fuel Cells and Infrastructure Technologies Plan, Multi-Year Research and Development Plan. (February 2005)

Two Hydrogen/CNG-fuelled internal combustion engine trucks at Powertech Labs fueling station in Surrey, BC.

Source: Powertech Labs.