Background Paper

Where's the Hydrogen Economy?

Publication No. 2010-16-E
1 February 2010

Dillan Theckedath

Industry, Infrastructure and Resources Division
Parliamentary Information and Research Service

Library of Parliament
Bibliothèque du Parlement

Where's the Hydrogen Economy?

(Background Paper)

HTML and PDF versions of this publication are available on Intraparl (the parliamentary intranet) and on the Parliament of Canada website.

In the electronic versions, a number of the endnote entries contain hyperlinks to referenced resources.

Ce document est également publié en français.

Library of Parliament ***Background Papers*** present and analyze various aspects of current issues in an objective, impartial manner. They are prepared by the Parliamentary Information and Research Service, which carries out research for and provides information and analysis to parliamentarians and Senate and House of Commons committees and parliamentary associations.

Publication No. 2010-16-E
Ottawa, Canada, Library of Parliament (2010)

CONTENTS

WHERE'S THE HYDROGEN ECONOMY?

1 INTRODUCTION

Hydrogen is the most common element in the universe, and has many uses in industrial and consumer applications. Hydrogen is also a key input in fuel cells, which are capable of producing electricity without harmful emissions – in fact, a hydrogen fuel cell (HFC) emits only water and heat.[1] Moreover, fuel cells are versatile and can be designed to power everything from a flashlight to a submarine.[2] With such promise, this technology has been the focus of the creation of a parallel "hydrogen economy," one aimed at supplanting the dominance of crude oil and coal-fired electricity. Yet, for all the potential of clean and portable power, the promise of HFCs is severely limited by the technical difficulties and costs associated with producing, storing, and transporting hydrogen. In the past, governments provided much support towards the development of this technology, but recently that support appears to be weakening. This paper will examine the state of the Canadian hydrogen and fuel cell industry and the general state of the global hydrogen economy, along with reasons why the hydrogen economy has not, thus far, lived up to expectations.[3]

2 HYDROGEN FUEL CELLS

A fuel cell is a device that uses an electrochemical process to produce electricity. Currently, the majority of fuel cells use hydrogen as the primary fuel. In simple terms, such devices combine hydrogen gas (H_2) and oxygen gas (O_2), which, in turn, produces electricity, water vapour (H_2O), and heat.[4] When using pure hydrogen, HFCs produce nearly zero amounts of greenhouse gases (GHGs) and other harmful emissions.[5] Additionally, fuel cells can be scaled to meet portable, stationary, remote, and back-up power requirements, as well as those for transportation.[6]

Fuel cells have been successfully employed in many applications, such as:

- passenger buses in Vancouver running on the Ballard Fuel Cell;[7]
- the Honda FCX Clarity, an HFC passenger car currently available for lease to customers;[8]
- a demonstration project whereby fuel cells provided electricity, heat, and hot water heating for a dormitory at the University of Toronto campus in Mississauga;[9] and
- the Angstrom A2 Fuel Cell Flashlight, powered by the Micro Hydrogen Fuel Cell.[10]

These and many other demonstration projects and commercial applications have shown HFCs to be safe, reliable, and efficient. They may also help address the need for clean power to counter the problems of climate change and increasing global energy demands.

3 CHALLENGES OF HYDROGEN FUEL CELL TECHNOLOGY

The advantages of HFCs come at a cost, however. First, HFCs use expensive precious metals like platinum (though this is only a fraction of their total cost). Second, although hydrogen can be obtained from many compounds (such as water, sugar, and natural gas),[11] energy is required to extract it from such compounds; hydrogen is an energy carrier and not an energy source.[12] Consequently, while HFCs themselves produce almost no emissions, the processes used to obtain the hydrogen can be sources of harmful GHGs.

The key challenge with HFCs (or any hydrogen-based technology), then, is the supply of hydrogen itself. It must be obtained by energy-consuming processes, such as steam-reforming of natural gas, or electrolysis of water.[13,14] Currently, 95% of hydrogen produced in North America is obtained by steam-reforming, because of the process's relatively low cost.[15,16] However, this method produces more carbon dioxide (CO_2) than it does usable hydrogen. To protect the environment, the excess CO_2 must be captured and treated, requiring further energy consumption.[17] Hydrogen can also be obtained through the relatively clean process of electrolysis of water, but this is a very expensive option given the amount of electricity required to treat sufficient quantities of water.[18] For example, according to one study, "when taking into account fossil fuel energy consumption and greenhouse gas emissions, the efficiency of a fuel cell vehicle employing hydrogen from natural gas should be at least 25–30% higher than a gasoline one to be competitive."[19] Thus, given the goal of producing clean energy, the complications associated with producing hydrogen for HFCs become evident.

Finally, further compounding the problem is hydrogen's low physical density: it is so light it must be highly pressurized for capture, transportation, and storage, requiring further energy and specialized technology.[20]

4 THE CANADIAN HYDROGEN AND FUEL CELL INDUSTRY

In 2007, the Canadian hydrogen and fuel cell industry employed some 2,000 people, with approximately 15% of them working for Canadian companies abroad. The breakdown by employer is as follows:[21]

- 81% work in the corporate sector;
- 14% work in the public sector; and
- 5% work in the academic and non-profit sectors.

The majority of employees work in British Columbia, followed by Ontario in second place. Given the highly technical nature of the work involved, workers in the hydrogen and fuel cell industry earned an average salary of $62,272 in 2007.[22]

In 2007, the Canadian hydrogen and fuel cell industry had revenues of $168 million, an increase of 26% from the previous year. The majority (51%) of market focus was portable and stationary power. Corporate and academic spending on research and development (R&D) amounted to $186 million. The top three sources of revenue were as follows:[23]

- product sales (58% of revenue);
- non-government R&D contracts (20% of revenue); and
- provision of services (15% of revenue).

Between 2001 and 2007, the Canadian hydrogen and fuel cell industry grew steadily, as evidenced by the following key metrics:[24]

- employment increased by 13%;
- revenue increased by 73%; and
- overall (including government) R&D spending increased by 18%.

Yet, while the Canadian hydrogen and fuel cell industry has experienced some key gains, recent analysis suggests that things may be changing. The 2008 *Canadian Fuel Cell Commercialization Roadmap Update* notes the following:[25]

> [A]ccess to funding from both public and private stakeholders is diminishing, and increasing sales and reduced operating costs have yet to lead to profitability. In Canada, investor interest remains weak and the funding required to increase Canadian manufacturing capacity to the levels needed for commercialization in near-term markets has not been forthcoming.

The report goes on to suggest that Canada may not be a country where "high-volume manufacturing plants will ultimately be located," and that "while Canadian companies can and should continue to participate in efforts related to improved and scaled-up manufacturing, our long-term competitive position in global markets will more likely … be associated with the development and demonstration of technology and in the production and storage of hydrogen."[26] This would suggest the future of the Canadian hydrogen and fuel cell industry – like that of so many other Canadian high-tech industries – will be based primarily on technology discovery and demonstration, rather than on manufacturing.

5 THE HYDROGEN ECONOMY

The current North American (and global) economy is heavily dependent upon the use of fossil fuels for both stationary and transportation power requirements. Most vehicles are fuelled by gasoline, a product of crude oil, and most residential and commercial electricity is obtained from coal-burning power plants.[27] The burning of fossil fuels contributes to pollution and GHGs.

In order for a society to change from petroleum-fuelled transportation to one based on HFCs, there would need to be in place a comprehensive infrastructure to support the new technology; that is, many elements would have to come together in order to move to a "hydrogen economy." First, vehicle manufacturers would have to produce

HFC-powered vehicles on a scale that could render them affordable compared to gasoline-fuelled vehicles. Second, there would have to be a network of hydrogen fuelling stations available to provide motorists with fuel. Third, sufficient production and distribution of hydrogen would be required in order to render the fuel affordable, again, compared to gasoline. Fourth, there would need to be a comprehensive regulatory system to ensure the safety and reliability of the storage, distribution, and use of hydrogen.

Similarly, to meet the needs of residential and commercial applications, much would be required in order to change from standard electricity production (i.e., dams, nuclear and coal facilities) to HFC-based power.[28] And whether this power would come from on-site dedicated power stations, or large-scale power hubs that distribute electricity to several consumers, a reliable hydrogen production and distribution system would need to be in place, along with a new regulatory framework. Given these challenges, strong government leadership is required to bring about a hydrogen economy.

In the past, there was much government and private support for investing in the R&D and eventual demonstration of hydrogen technologies, particularly HFCs, given their promise of clean, reliable, and efficient power. In the 20-year period from 1982 to 2002, "government support to the fuel cell industry totalled approximately $179 million in grants, contributions and loans."[29] In 2003, the Government of Canada introduced the Hydrogen Economy Initiative, a $215-million action plan to aid in the development of a hydrogen economy.[30] Consequently, several government programs were created: for example, Industry Canada began the H_2EA (Hydrogen Early Adopters) Program, a contribution program to support HFC and hydrogen technology demonstration projects. Several other government departments (including National Defence, Transportation, and Environment) have also provided support through procurement or transfer payments. Consequently, among the key benefits of government support is its success in stimulating private-sector investment.[31]

A key component of that action plan is the BC Hydrogen Highway, a public-private-partnership demonstration program located in British Columbia. Various government and private stakeholders have collaborated to create a hydrogen network, composed of hydrogen refuelling stations, technology providers, hydrogen producers, and vehicle manufacturers. A similar program exists in California, the California Hydrogen Highway.[32] The goal of the BC project is to create a "real-world" system to showcase this technology, as well as to educate the public on hydrogen technologies. A secondary objective of this initiative was to showcase a Canadian technological success at the 2010 Vancouver Olympic Winter Games. Moreover, this comprehensive demonstration is a scale model of a potential hydrogen economy.[33]

6 GOING FORWARD

In 2003, the Government of Canada introduced the *Canadian Fuel Cell Commercialization Roadmap*, outlining the key plans to transform HFC technology into a commercially viable market. According to the 2008 *Canadian Fuel Cell Commercialization Roadmap Update*, national governments "remain committed to developing hydrogen and fuel cell solutions, [but] are hedging their investments across a mix of technologies."[34] While the automotive sector continues to invest in HFC R&D, its progress will be influenced by the development and establishment of a hydrogen fuelling infrastructure which has not yet been addressed by energy-producing firms, perhaps for the following reasons:[35]

- **Hydrogen Production and Delivery.** The high cost of hydrogen production, low availability of hydrogen production systems, and the challenge of providing safe production and delivery systems are all early penetration barriers. … Hydrogen delivery options need to be determined and assessed as part of system demonstrations for every potential production technology. …
- **Public Acceptance.** … Education of the general public, training personnel in the handling and maintenance of hydrogen system components, adoption of codes and standards, and development of certified procedures and training manuals for fuel cells and safety affect hydrogen's acceptance as a fuel.

While "Canadian companies are well positioned to play an important role in the commercialization of fuel cell automobile technologies and provide opportunities for early investment in the hydrogen infrastructure for mass consumer markets," the current industry focus appears to be elsewhere.[36] Sector analysis from Industry Canada suggests the current Canadian market is more likely to be focused on materials handling, back-up power, transit buses, and portable electronics.[37]

In light of these considerations, it would appear that in the HFC landscape, the push to develop a supporting hydrogen economy has lost some of its steam. As national governments spread their attention across several technologies, the result will be a reduced importance allotted to hydrogen technologies. This lowered interest is further exemplified by current Canadian government practices; for example, Industry Canada did not renew the H_2EA Program for 2008, and there is no mention of funding for hydrogen or fuel cell technology in recent budgets.[38] (For example, Budget 2010 is considered an "innovation budget," given the emphasis on innovation for job creation; yet, there is no specific stated funding allocation for hydrogen or fuel cells.)[39] And while governments and industry talk about the critical importance of developing a hydrogen infrastructure to supply a hydrogen economy, there has been limited action to support that goal.

The American experience has been very similar to that of Canada. Since the 1970s, the US federal government has funded fuel cell R&D (though not always limited to hydrogen-based technologies).[40] In the first years of the 21st century, the United States invested significant funds to reduce its dependency on foreign oil and to reduce pollution – in the 2003 State of the Union address, President Bush proposed a $1.2-billion plan for hydrogen technology R&D.[41] However, recently approved statutes, such as the *American Recovery and Reinvestment Act of 2009*, have allocated only $40 million for fuel cell deployment.[42] Furthermore, the *American Clean Energy and Security Act of 2009* does not include specific appropriations for the development of hydrogen technologies, and includes references to grants for developing "clean energy technology products" only, of which fuel cells are but one of many types listed.[43] Lastly, the Obama administration has shown reduced support for fuel cell R&D, with Energy Secretary Chu stating that conversion to a hydrogen economy in the next 10–20 years is unlikely, given the lack of infrastructure and the current state of fuel cells; instead, the government will focus funds on fuel cell research in the area of stationary and portable power.[44] And while President Obama ultimately signed a bill increasing HFC funding by $45 million in 2009, it was only after Congress presented him with legislation that did not include the administration's intended hydrogen R&D reductions.[45]

In sharp contrast, the world's other key HFC countries appear to be maintaining or increasing their funding to hydrogen and fuel cell technology. Consider the following figures from the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE):

- Germany is continuing to fund HFC programs, some of which go to 2013;[46]
- Japan is continuing to fund HFC programs to 2014;[47] and
- South Korea (the Republic of Korea) appears to have aggressive plans for commercialization and export of HFC technology, including strong government support.[48]

7 CONCLUSION

Evidenced by both current Canadian and US government actions, and the success of Canadian firms, the near-term focus of hydrogen economy stakeholders is the R&D and commercialization of "stand-alone" HFC products (i.e., stationary and portable power supply), and not "network-based" HFC systems such as cars and trucks, which would require the creation of a hydrogen infrastructure. Given the current constraints (scientific and financial) of producing and distributing hydrogen, stand-alone products and services may allow for a much faster increase in the adoption and commercialization of hydrogen technologies, on a large scale. It is evident that a comprehensive hydrogen economy is not likely to be realized in the near future, given the void in investment and development of a hydrogen distribution infrastructure, technical obstacles, and comparatively higher costs of using HFCs in large-scale applications relative to other established alternatives.

In conclusion, the future of the Canadian hydrogen and fuel cell industry and of the hydrogen economy may lie in the continued success of Canadian R&D and demonstration of hydrogen technology. This may be furthered with renewed government support, which has previously achieved the goal of stimulating private-sector investment.

With increased investment, the hydrogen and fuel cell industry may be able to achieve economies of scale, which should help lower costs, and thus prices. Lower prices, increased consumer awareness and confidence in HFCs, and, ultimately, increased demand for hydrogen-based technologies may accelerate commercialization. Given that Canadian companies have developed expertise in a wide range of hydrogen technologies, this breadth of knowledge and experience should position Canada to be a dominant player in a potential hydrogen economy, should it ever materialize as hoped.

NOTES

1. US Department of Defense, Fuel Cell Test and Evaluation Center, "Fuel Cell Basics."
2. Germany currently employs a fuel-cell powered submarine, the U212; see naval-technology.com, "U212 / U214 Attack Submarines, Germany."
3. In this paper, "North American" refers to the integrated economies of Canada and the United States.
4. US Department of Defense, Fuel Cell Test and Evaluation Center, "Fuel Cell Basics."
5. Natural Resources Canada, Office of Energy Efficiency, "Business: Transportation – Environmental benefits," 30 October 2008.
6. Canadian Hydrogen and Fuel Cell Association, "About Fuel Cells."
7. Ballard Power Systems Inc.
8. Honda Motor Company, "FCX: Fuel Cell Electric Vehicle."
9. University of Toronto at Mississauga, "Fuel Cells," 19 November 2009. Here, the fuel cells were so effective, they were able to *provide* power to the main electricity grid on campus.
10. Angstrom Power.
11. Natural Resources Canada, Office of Energy Efficiency, "Business: Transportation – Fuel cells and hydrogen," 17 April 2009.
12. Ibid.
13. Los Alamos National Laboratory, Chemistry Division, "Hydrogen," 15 December 2003.
14. US Energy Information Administration, "Hydrogen."
15. Steam-reforming is the process of applying steam to the methane in natural gas, in order to obtain hydrogen and carbon oxides; see New York State Energy Research and Development Authority, "Hydrogen Production – Steam Methane Reforming (SMR)."
16. BC Hydrogen Highway, "Myths and Misconceptions."
17. New York State Energy Research and Development Authority, "Hydrogen Production – Steam Methane Reforming (SMR)."
18. US Energy Information Administration, "Hydrogen."
19. Mikhail Granovskii, Ibrahim Dincer and Marc A. Rosen, "Life Cycle Assessment of Hydrogen Fuel Cell and Gasoline Vehicles," *International Journal of Hydrogen Energy*, Vol. 31, No. 3, March 2006, pp. 337–52.
20. Cutler J. Cleveland, ed., "Hydrogen Storage," *Encyclopedia of Earth*, 24 August 2008.
21. Industry Canada, *Canadian Hydrogen and Fuel Cell Sector Profile 2008*, Ottawa, 2008.
22. Ibid.
23. Ibid.
24. Ibid.
25. Industry Canada, *Canadian Fuel Cell Commercialization Roadmap Update*, Ottawa, 2008 (see "A Near-term Market Approach").
26. Ibid.

27. Over 70% of American electricity is obtained by burning fossil fuels. In Canada, the amount is about 20%. See US Energy Information Administration, "Electricity in the United States"; Statistics Canada, "Electric Power Generation, Transmission and Distribution: Analysis – Electricity Generation," 20 April 2009.
28. While producing hydrogen requires power, this power could come from solar and wind sources, which would make the entire life-cycle process relatively cleaner.
29. Industry Canada, *Canadian Fuel Cell Commercialization Roadmap*, Ottawa, 2003 (see "Stakeholders – Government").
30. Industry Canada, *Canadian Fuel Cell Commercialization Roadmap Update* (see "Preface").
31. See, for example, "Hydrogen and fuel cell industry converges on Ottawa to push for renewal of key programs," *Re$earch Money*, 22 September 2009.
32. California Hydrogen Highway.
33. BC Hydrogen Highway.
34. Industry Canada, *Canadian Fuel Cell Commercialization Roadmap Update* (see "Executive Summary").
35. US Department of Energy, "Fuel Cell Technologies Program – Technology Validation."
36. Industry Canada, "Hydrogen and Fuel Cells."
37. Industry Canada, *Canadian Fuel Cell Commercialization Roadmap Update* (see "Executive Summary").
38. Canada, Department of Finance, *Budget 2009*, 27 January 2009.
39. Canada, Department of Finance, *Budget 2010*, 4 March 2010.
40. US Department of Energy, "Future Fuel Cells R&D," 17 December 2009.
41. CNN, Transcript of the 2003 State of the Union address, "Part 4: Energy."
42. International Partnership for Hydrogen and Fuel Cells in the Economy (United States of America).
43. US House of Representatives, *American Clean Energy and Security Act of 2009*.
44. David Biello, "R.I.P. hydrogen economy? Obama cuts hydrogen car funding," *Scientific American*, 8 May 2009.
45. House Resolution 3183, *Energy and Water Development and Related Agencies Appropriations Act, 2010*.
46. International Partnership for Hydrogen and Fuel Cells in the Economy [IPHE] (Germany).
47. IPHE (Japan).
48. IPHE (Republic of Korea).