



Industry
Canada

Industrie
Canada

Final Evaluation of the Hydrogen Early Adopters Program

FINAL REPORT

March 25, 2008

Tabled and approved at DEC
on June 9, 2008

Canada 

This publication is available upon request in accessible formats. Contact:

Multimedia Services Section
Communications and Marketing Branch
Industry Canada
Room 264D, West Tower
235 Queen Street
Ottawa ON K1A 0H5

Tel.: 613-948-1554

Fax: 613-947-7155

Email: multimedia.production@ic.gc.ca

Permission to Reproduce

Except as otherwise specifically noted, the information in this publication may be reproduced, in part or in whole and by any means, without charge or further permission from Industry Canada, provided that due diligence is exercised in ensuring the accuracy of the information reproduced; that Industry Canada is identified as the source institution; and that the reproduction is not represented as an official version of the information reproduced, nor as having been made in affiliation with, or with the endorsement of, Industry Canada.

For permission to reproduce the information in this publication for commercial redistribution, please email: copyright.droitdauteur@pwgsc.gc.ca

Cat. No. Iu4-139/2008E-PDF

ISBN 978-1-100-10137

60487

Aussi offert en français sous le titre *Évaluation finale du Programme des adhérents pionniers de l'hydrogène.*

TABLE OF CONTENTS

Executive Summary	i
1. Introduction	1
1.1 Background.....	1
1.2 Study Objective	1
1.3 Study Approach	1
1.4 Study Methodologies	2
1.5 Study Limitations and Mitigation Measures.....	4
2. Sector Overview	5
2.1 International Sector Profile.....	5
2.2 Canadian Sector Profile	5
3. Program Profile.....	10
3.1 Program Information	10
3.2 Project Information.....	12
4. Findings: Relevance	16
4.1 Alignment with Industry Needs.....	16
4.2 Evolution of the Industry	16
5. Findings: Success	19
5.1 Overall Conclusion	19
5.2 Technical and Organizational Learning.....	19
5.3 Commercial Success.....	20
5.4 Codes and Standards.....	21
5.5 Awareness and Acceptance	22
6. Findings: Design, Implementation, and Cost Effectiveness.....	25
6.1 Program/Project Design.....	25
6.2 Program Implementation	27
7. Conclusions	30

Appendix A – Steering Committee Members

Appendix B – List of Interviewees

Appendix C – Case Studies

Appendix D – Partnerships and Coalitions Aimed at Obtaining Funding from h2EA

NOTE:

Appendices are available via an Access to Information Request.

EXECUTIVE SUMMARY

Background

The Hydrogen Early Adopters (h2EA) program was launched in late fall of 2003 with the goal of addressing the need to accelerate market adoption of hydrogen technologies and other hydrogen-compatible technologies that facilitate the transition to a hydrogen economy. Through Technology Partnerships Canada (TPC) (since renamed the Industrial Technologies Office (ITO)), support has been targeted on consortia comprised of public and private sector partners to validate these technologies through demonstrations, and showcase Canadian capabilities.

The evaluation was managed by the Audit and Evaluation Branch (AEB) of Industry Canada. Progress was reported to an Evaluation Study Steering Committee for feedback during the course of the study (see Appendix A for a list of Steering Committee members). Hickling Arthurs Low (HAL) Corporation was engaged by Industry Canada (IC) to conduct the evaluation.

Program Overview

The h2EA program started in the fall of 2003, and is currently scheduled to sunset in March 2008. The program was launched as part of the government's five year, \$215 million, Climate Change Plan for Canada, which initially allocated \$60 million for the h2EA program. \$10 million of this was allocated to the Canadian Transportation Fuel Cell Alliance (CTFCA) managed by NRCan to extend that program by two years.

In the period from 2003 to 2006, over 40 coalitions formally expressed interest in obtaining funding from h2EA. These distinct partnerships represented 87 organizations, 39 of whom were firms constituting 60% of the Canadian h2 industry in 2003¹.

Shifting government priorities and a review of expenditures in early 2006 led to a funding reduction for h2EA and the termination of spending on any new projects. At the time of this evaluation, the program had contracted six projects in total; one was terminated by mutual consent, one was inactive, and four became active. The four active projects represent over 50 companies, ranging from technology providers to funding partners to end-users and secondary suppliers, and cover a wide range of technologies and applications. In total, \$20.5 million was committed to h2EA projects as indicated in the Table 1.

¹ Key Performance Indicators, h2EA Program, February 20, 2007

Table 1 - h2EA Program Investments

Project Name	Investment	Consortium Participants
Hydrogen Solution for Utility Vehicles	\$4.2 million	Hydrogenics Corporation, Deere & Company, Hydrogenics Test Systems Inc., Emerson Network Power Canada
Stationary Fuels for Residential Heating and Power Generation	\$935,000	Fuel Cell Technologies Ltd., Ontario Power Generation Inc., and the University of Toronto at Mississauga
H2ICE Shuttle Bus Demo	\$4.2 million	Ford Motor Company of Canada Limited and Advanced Technologies and Fuels Canada Inc.
Integrated Waste Hydrogen Utilization Project	\$6.0 million	Sacré-Davey Innovations Inc., Sacré Consultants Ltd., Westport Innovations Inc., Westport Research Inc.
PEI Wind-Hydrogen Village Project*	\$5.1 million	Hydrogenics Corporation and Prince Edward Island Energy Corporation.

* This project has not proceeded and therefore was not included in this study.

Study Approach

As a final evaluation, the study addressed the evaluation issue areas of relevance, program design and delivery, program success (with a focus on results), and cost effectiveness, using three lines of enquiry: document review; interviews with representatives of TPC/ITO, Industry Canada, Natural Resources Canada (NRCan), project consortium members and industry associations; and, case studies of the four h2EA projects.

The study was conducted in two phases, Phase 1 covering two projects (Hydrogen Solution for Utility Vehicles, and Stationary Fuels for Residential Heating and Power Generation) completed or nearing completion in FY 2006-2007, and Phase 2 covering the remaining two projects (Hydrogen Internal Combustion Engine (H2ICE) Shuttle Bus Demonstration, and Integrated Waste Hydrogen Utilization Project) ongoing through FY 2007-2008.

Study Methodologies

Completed interviews numbered 42 for Phases 1 and 2 covering TPC/ITO staff, Industry Canada and NRCan, project lead firms, project consortia members, suppliers, supporters, and individuals involved with unfunded projects. Case studies were prepared on all four funded projects to provide a more in-depth understanding of their rationale, the roles and responsibilities of participants, implementation issues, objectives achievement, and cost-effectiveness considerations. Site visits were undertaken as part of the case studies to provide a fuller picture of how the program has been implemented.

Evaluation Findings

Relevance

The h2EA program was seen by government and industry representatives as being in line with industry needs when it was established in 2003. The industry has evolved substantially since the program was created in terms of technological and industrial developments including the achievement of some commercial successes. Organizations within the industry, however, have evolved at different rates, and as a result there are diverging views on how best to support the industry's continued development.

Success

The number of projects funded through the h2EA program is within the original estimates; however, fewer demonstrations have been supported within these projects than expected, reducing the range of developmental experience in hydrogen and fuel cell applications for the Canadian industry. While the original objectives to support the creation and development of a Hydrogen Highway in BC and Hydrogen Village in Toronto have not yet been fulfilled, progress has been made. Overall, there has been good success with the four h2EA projects that proceeded.

Most companies involved have experienced technical learning, and general improvements in their capabilities in hydrogen technology. The real world experience that demonstrations have brought is considered a vital learning experience and has in some cases allowed for organizational learning as well. The two larger, more complex projects have benefited from a greater degree of learning due to the wider range of technology demonstrated, than have the smaller projects.

Commercial success has been negligible for all but Hydrogenics Corporation, which, through its demonstration of a backup power system, was able to secure a large follow-on order from an American back-up power supply company involved as a contractor in the demonstration. Though commercial success has been limited, h2EA has advanced hydrogen technologies closer to commercialization through the demonstrations.

Overall, the demonstrations have revealed that codes and standards have been less of a barrier than originally anticipated by many companies. All demonstrations succeeded in obtaining the necessary permits and approvals. The key challenge for many was in communicating how the demonstrations worked and how safety concerns were addressed to the various parties involved in assessing compliance.

General awareness and acceptance of hydrogen technology has occurred at two main levels. The first is among officials and individuals directly involved in the demonstrations, including first responders (fire, police, ambulance etc.), technicians and mechanics and building managers. All demonstrations have reported important strides in advancing awareness at this level. At the broader level of public awareness, results have varied for a number of reasons, including: the level of public visibility of the demonstration, the degree to which the public has access to the

demonstration sites, the number of outreach sessions, and the fact that two of the projects (the Ford and Sacré Davey projects) had not completed their demonstrations at the time of the evaluation.

Program Design and Implementation

Program/Project Design

Participants agreed that collaborative arrangements are a key factor in technology and market development for the industry. They generally accepted the program requirement to establish a consortium; however, some noted they had been able to achieve a high level of technology development within the supply chain and with a broad range of firms in other projects without this requirement. The concept of the consortia was ultimately accepted by applicants, however, the liability clause, which was put in place in order to minimize the financial risk to the government, caused significant difficulties for some companies. The requirement for all members of the consortium to be joint and severally liable for the project was a financial risk that some companies were reluctant to accept.

While the consortium requirement and the related liability clause were put in place to both encourage program success and minimize the financial risk to government, the evaluation revealed other characteristics of the projects that also played a role in achieving results:

- *Project size:* The two larger projects with many sub-components – the Hydrogenics and Sacré Davey projects - were better able to demonstrate results than the smaller, less complex projects.
- *Type of end-user:* The involvement of firms as end-users as opposed to institutions helped to showcase market applications, furthering the technology's development.
- *Lead firm financial situation:* Lead firms that were financially sound and/or sufficiently endowed with managerial skills, tended to be in a better position to deal with the administrative requirements of the program.

Implementation

Program Reach: The program reached its intended target firms. These target firms (most of whom were SMEs, exceptions being Ford Canada, Deere & Company, Purolator Courier and Bell Canada) consisted of a full supply chain of technology providers, users and suppliers as well as supporting government organizations.

Application Process: The mechanism of a competitive application process was viewed as appropriate by most successful applicants that were interviewed, but many, both successful and unsuccessful, found the process to be rigid and time consuming. Interaction between the sponsoring program and companies in a developing sector like hydrogen and fuel cells is important at all stages of the application process, from contracting to reporting on results.

It was suggested that sufficient resources at the departmental level were not available at the start of the program to deal effectively with the high level of uptake.

Due Diligence: The h2EA program was generally considered to be too rigid in its development and application of procedures for an industry that is not yet fully mature and subject to rapid technological change. Terms and conditions of the program were appropriate for demonstrations of existing technologies (which was the intent of the program) but less so for those still undergoing development, which, while unanticipated, included some of the technologies demonstrated through the funded projects. The reassignment of files, necessitated by changes in staffing levels over the project lifecycles, further complicated the situation, resulting in difficulties in providing seamless support in the administration of the funded projects.

Conclusions

Technology developers in Canada's hydrogen industry are typically small or medium-sized with insufficient resources to absorb heavy reporting requirements, lengthy negotiations or payment delays. In their view, a flexible and responsive program structure is needed to assist firms in achieving program objectives. At the same time, there is a need to ensure the exercise of due diligence. Given this situation, the following suggestions may be useful when considering the design of future programs:

(i) The consortium model of inter-firm collaboration, which is typically reserved for pre-competitive research goals, is only one way to promote inter-firm collaboration. Basic contractual relationships can be very successful in promoting inter-firm learning and knowledge sharing within the supply chain, provided the projects are sufficiently large so as to be beyond the capabilities of any one firm.

(ii) The intent of technology demonstration program is to absorb part of the risk inherent in advancing new technologies towards commercialization. Project requirements and due diligence processes should be designed to reflect that intent.

(iii) The level of development of the technologies being proposed for demonstration projects is critical to the achievement of program objectives. Terms and conditions that are appropriate for demonstrations of proven technologies in key market applications may be less so for technologies that may require further development during the demonstration phase.

The Hydrogen Early Adopters (h2EA) program has sunset on March 31, 2008. As a result, the evaluation report does not contain any recommendations, and a management action plan from the program was not required. The management response indicated that the program concurs with the findings and conclusions of the evaluation.

1. INTRODUCTION

1.1 Background

The Hydrogen Early Adopters (h2EA) program was launched in late fall of 2003 with the goal of addressing the need to accelerate market adoption of hydrogen technologies and other hydrogen-compatible technologies that facilitate the transition to a hydrogen economy. Through Technology Partnerships Canada (TPC) (since renamed the Industrial Technologies Office (ITO)), support has been targeted on consortia comprised of public and private sector partners to validate these technologies through demonstrations, and showcase Canadian capabilities. These partnerships have involved integrating hydrogen-compatible technologies in hydrogen production, storage and distribution, demonstrated by end users of stationary and mobile applications.

1.2 Study Objective

The objective of the study is to undertake a final evaluation of the h2EA program based on the evaluation issues and research questions, and performance measures identified in the h2EA Results-Based Management and Accountability Framework (RMAF), 2003. The evaluation is responding to a Treasury Board Secretariat requirement and was conducted in accordance with Treasury Board policies.

As the program will be sunsetting on March 31, 2008, the report does not include recommendations. The focus of the evaluation is on program level results determined through an examination of program experience at the project level.

1.3 Study Approach

The study approach involved consideration of the evaluation issue areas of relevance, program design and delivery, program success, and cost effectiveness. The approach used three lines of enquiry: document review; interviews with representatives of TPC/ITO, Industry Canada, Natural Resources Canada (NRCan), consortium members and industry associations; and case studies of the four funded h2EA projects.

The evaluation was managed by the Audit and Evaluation Branch (AEB) of Industry Canada. Hickling Arthurs Low (HAL) Corporation was engaged by Industry Canada (IC) to conduct this evaluation of the h2EA program. The study was conducted in two phases, Phase 1 covering two funded projects (Hydrogen Solution for Utility Vehicles, and Stationary Fuels for Residential Heating and Power Generation) completed or nearing completion in FY 2006-2007, and Phase 2 covering the remaining two funded projects (Hydrogen Internal Combustion Engine (H2ICE) Shuttle Bus Demonstration, and Integrated Waste Hydrogen Utilization Project) ongoing through FY 2007-2008.

Progress was reported to an Evaluation Study Steering Committee for feedback during the course of the study (see Appendix A for a list of Steering Committee members). This final report on the

h2EA evaluation incorporates the results of the Phase 1 evaluation, submitted in a preliminary report on June 8, 2007, as well as the results of the Phase 2 evaluation.

1.4 Study Methodologies

The lines of enquiry are as follows:

1.4.1 Document review

Documents reviewed included:

- h2EA RMAF and Risk-Based Audit Framework (RBAF)
- h2EA Six Month Progress Report
- h2EA Terms and Conditions
- Program Audit of h2EA
- Key Performance Indicators for h2EA
- Project documents and files: contribution agreements, proposals, progress reports, annual reports, communication documents
- Press articles and releases

1.4.2 Consultations

Interviews were held with representatives of the interview groups listed in Table 1; the list of interviewees is given in Appendix B. Completed interviews numbered 42 for Phases 1 and 2 covering TPC/ITO staff, Industry Canada and NRCan, project lead firms, consortia members, suppliers, supporters, and unfunded projects. The companies and organizations interviewed included those given in Chapter 3 (Project Information) with the addition of the lead companies for four unfunded projects, Ballard (Vancouver), Solar Hydrogen Energy Corporation (Saskatoon), University of British Columbia (Vancouver) and Air Liquide (Montreal), as well as representatives of the Canadian Hydrogen Association, Hydrogen & Fuel Cells Canada, and the Hydrogen Village Project.

The questions included in the interview guides were based on the RMAF and, together with the list of proposed interviewees, were reviewed with AEB and program representatives beforehand. Consultations with representatives of TPC/ITO, Industry Canada and NRCan, located in Ottawa, were conducted in-person, as were interviews with project participants contacted as part of the site visits supporting the case studies; other interviews were by telephone. The consultations were semi-structured, allowing for effective probing of questions set out in interview guides. Respondents were assured that their responses would be aggregated and that individual comments would not be included in the report without their prior consent.

Table 1: Phases 1 and 2 Consultations

Phase 1 Interview Groups Project	Number of Interviews	
	Fuel Cell Technologies	Hydrogenics
TPC/ITO Staff	1	1
Regional Agencies/Other Government Departments	1	1
Project Lead Firms	1	1
Consortia Members	1	3
Suppliers	1	1
Supporters	3	3
Project Totals	8	10
Unfunded Projects	4	
Phase 1 Total	22	

Phase 2 Interview Groups Project	Number of Interviews	
	Sacré Davey	Ford
TPC/ITO Staff	2	1
Other Government Departments	2	1
Project Lead Firms	1	1
Consortia Members	2	1
Suppliers	4	2
Supporters	2	1
Project Totals	13	7
Phase 2 Total	20	

1.4.3 Case Studies

Case studies were prepared on the two Phase 1 and two Phase 2 projects (i.e. the universe of funded projects) to provide a more in-depth understanding of the rationale for the projects, roles and responsibilities of participants, implementation issues, objectives achievement (results), and cost-effectiveness considerations. As noted, site visits were undertaken as part of the case studies to provide a fuller picture of how the program has been implemented, including issues of program design, how well the projects moved towards planned objectives, and what barriers had been encountered. The four case studies are included as Appendix C.

1.5 Study Limitations and Mitigation Measures

The four h2EA projects that we examined were not all at the same stage of implementation at the start of the study and therefore could not all be evaluated at the same time. To mitigate this limitation, the study was divided into two phases with Phase 1 dealing with the two projects that were to be completed in FY 2006-2007 and Phase 2 with the two projects to be completed in FY 2007-2008. The result of the two phased approach was a lengthening of the study; to maintain continuity through the gap in the two phases, a preliminary report was produced on the first phase results.

Another broad concern for the study was the small number of projects and therefore the possible limitations on generalizing on the results for the whole Canadian hydrogen and fuel cell industry. That said, the companies involved in the projects are of varying size representing a reasonable cross section of the industry including fuel supply, fuel storage, and fuel usage both stationary and mobile in the public and private sectors. As well, the projects were all studied in detail through the case study approach. Therefore, we believe that the results are indicative of how the industry as a whole would have responded to the h2EA program including the issues faced and the lessons learned.

A more specific concern relates to the timing of the evaluation. The demonstrations of the two Phase 2 projects have not been running long enough to allow for a full assessment of project results. The evaluation, however, revealed no evidence of diminishing performance in the projects. It is expected that the evaluation of the projects at this stage is a fair representation of the situation of the projects at the end of the demonstration period which is expected to be approximately one year after the h2EA program ends.

A final potential limitation of the study was the winding down of a project partner in Phase 1 while the evaluation was underway. While this difficulty complicated the preparation of the project case study, the necessary information and interview responses were eventually obtained to enable an assessment to be made. No other difficulties in accessing interviewees or data were encountered.

Overall, it is believed that the evaluation findings and conclusion are reliable and represent an accurate assessment of the program.

2. SECTOR OVERVIEW

2.1 International Sector Profile

The hydrogen and fuel cell industry has, in recent years, been the focus of considerable attention world-wide as technological advances in hydrogen technology have brought forward the prospects of a ‘hydrogen economy’, and with it, promises of an environmentally friendly energy carrier for everything from cars to everyday appliances. Indeed, demonstrations validating the technology in the transport sector are now common, having benefited from increased public and private support. The International Energy Agency, an international energy policy organization supported by 27 countries, estimates that some US\$1billion is being invested annually in public research and development, prototypes and demonstrations of hydrogen based vehicles and related infrastructure.² In the state of California alone, over one hundred vehicles and seventeen fuel stations are being tested.

Despite these efforts, the industry is still considered to be in the early stages of development. Since 1994 when DaimlerChrysler (then Daimler) demonstrated the world’s first fuel cell, NECAR 1, the global industry has managed to produce only prototypes and test vehicles, with frequent promises of ‘commercialization within 5 years’ proving overly optimistic.³ Despite the slower-than-anticipated development, the industry continues to expand as more and more companies undertake research and development (R&D) efforts in hydrogen technology. New firms are emerging in Europe, Australia and Asia, and large multinational corporations, including Dupont, 3M, and Johnson Matthey, along with most of the world’s largest automotive manufacturers such as General Motors, DaimlerChrysler, Nissan, Honda, Toyota, Ford and Hyundai are becoming major players.

2.2 Canadian Sector Profile

2.2.1 Strengths of the Canadian Sector

Canadian firms, for their part, have long been recognized as global leaders in the industry, having been involved in several important industry developments. Ballard, of Burnaby B.C. for example pioneered the technology that made the NECAR 1 possible, and more recently, Hydrogenics landed the largest order yet to manufacture and supply fuel cells. As Table 1 shows, Canada is important globally both as a headquarters and manufacturing location for fuel cells.

² Mytelka and Boyle, “Policy Brief: Hydrogen Fuel Cells and Transport Alternatives: Issues for Developing Countries, United Nations University No. 3. 2006.

³ Carola Hanisch, 1999. “Powering Tomorrow’s Cars” in *Environmental Science and Technology* 33/21.

Table 1: Canadian Hydrogen and Fuel Cell Industry in a Global Context.

Leading Countries	Headquarters of Fuel Cell Activities	Location of Manufacturing
USA	40%	28%
Canada	30%	23%
Japan	8%	13%
Germany	9%	12%
China	-	3%
United Kingdom	3%	2%
Other	10%	19%

Source: PriceWaterhouseCoopers 2006 *Worldwide Fuel Cell Industry Survey*. Data is based on a survey of 181 organizations.

In employment terms, the Canadian industry is, however, relatively small. According to the Canadian Hydrogen and Fuel Cell Sector Profile 2005, the hydrogen and fuel cell industry employed 2,056 people in 2004. Private sector investment in innovation in Canada is estimated at over \$100,000 per employee, with \$237 million spent on research and development in 2004. Over the past five years, private sector research and development expenditures total over \$1 billion. As a result of this investment, Canadian industry is positioned to benefit significantly as the world market develops to its full potential. Global demand for hydrogen and fuel cell technologies is projected to be more than \$18 billion by 2013⁴.

Canadian hydrogen and fuel cell capabilities cover most types of fuel cell technologies, components, systems supply and integration, fueling systems, fuel storage, and engineering and financial services. With a solid foundation of capabilities, Canada stands to be amongst the leaders as hydrogen and fuel cells move towards commercialization. This expertise and leadership has been achieved, in large part, through a high level of collaboration between government and industry.

Hydrogen & Fuel Cells Canada considers that there are four areas in which Canada can exploit major opportunities:

(i) Micro/Portable Market - early market opportunities for consumer and industrial applications include laptop devices, flashlights, cell phones, scanners, communication handsets and various military applications.

(ii) Stationary Market - stationary fuel cells, both hydrogen-powered and high efficiency, near zero emission fossil fuel powered, can be used in a variety of applications, including off-grid and backup power, residential electricity and heating, and distributed power generation.

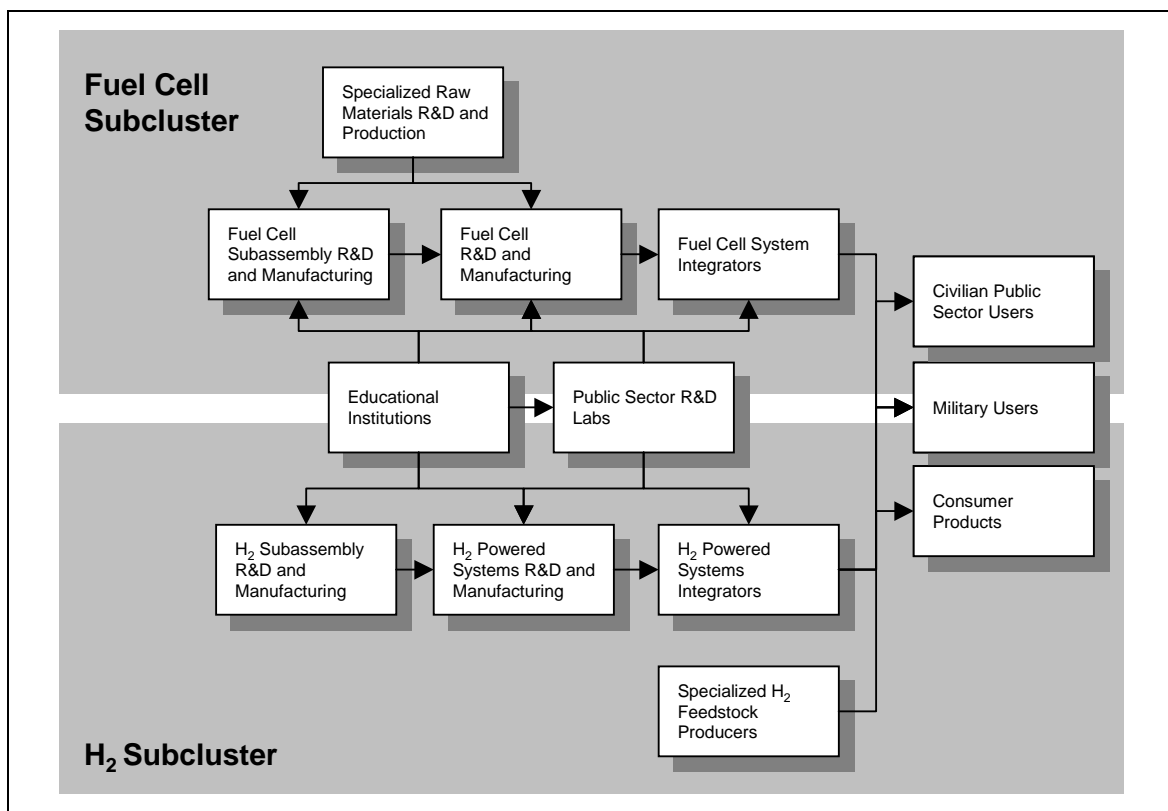
⁴ Hydrogen and Fuel Cells, Danish Trade Commission, <http://www.ambottawa.um.dk/da/menu/Eksportraadgivning/Markedsmuligheder/Sektoranalyser/MiljoeOgEnergi/Hydrogen+and+fuel+cells/>, accessed Feb 25, 2008.

(iii) Mobile Market - applications include hydrogen-powered automobiles, trucks, buses, locomotives and industrial support vehicles. Hydrogen internal combustion engines are an important bridge technology for establishing a mass market for fuel cell automobiles.

(iv) Hydrogen Infrastructure - possibilities include hydrogen captured from waste streams, electrolytic production, steam methane reforming, purification, distribution, storage and fueling systems, large-scale hydrogen production, and hydrogen production from nuclear, coal gasification and biomass.

A recent study of the British Columbia fuel cell cluster⁵ has shown how the industry has developed through the presence of a chain of specialized firms that supply the unique inputs to the fuel cell manufacturers and through the specialized downstream system integrators and users who have taken the prototype models of fuel cells and tested them in a wide variety of applications. These linkages can be seen as a value chain that exists for fuel cell development as well as for the production of hydrogen-based fuels as shown in the top half and bottom half respectively of Figure 1.

Figure 1: Fuel Cell and Hydrogen Value Chains



The hydrogen-based fuels that are used for fuel cells can also be used in many other applications, with similar efficiencies and reductions in pollution. For example, as demonstrated by Westport

⁵ Cluster Studies for NRC Technology Cluster Initiatives, Final Report, Hickling Arthurs Low Corporation, August 23, 2006

Innovations, a consortium member in the Integrated Waste Hydrogen Utilization Project, hydrogen can be used in specially adapted diesel cycle engines with resulting gains in cycle efficiencies and reductions in greenhouse gas pollution.

2.2.2 Recent Changes in the Canadian Sector

Over the course of the h2EA program, there have been some important and, indeed, symbolic changes in the hydrogen industry, particularly among some key players. Ballard, long viewed as Canada's icon in mobile hydrogen technology, has recently transferred its automotive based intellectual property to a new company owned by Daimler, Ford and Ballard⁶.

Ballard will continue to develop fuel cell technology (with access to all the intellectual property that arises from the new company for use in non-automotive fuel cells) for transit buses and shuttle buses throughout the world, and other applications such as fuel cell forklifts, stationary back-up power and co-generation for residential use (as they are doing in Japan). Ballard has recently signed supply agreements with Plug Power (forklifts for Wal-Mart)⁷, Exide Technologies (forklift trucks)⁸ and Voller Energy Group (back-up power)⁹.

Hydrogenics, another key player in the industry and benefactor of h2EA, has also been undergoing significant changes, having gone through two waves of cut backs in the last year in its efforts to reduce costs and realign itself for manufacturing¹⁰.

⁶ News release, "Ballard Confirms Close of Transaction to Sell Automotive Fuel Cell Assets; Company to Concentrate on Commercial Markets", January 31, 2008, accessed on website March 26, 2008 <http://phx.corporate-ir.net/phoenix.zhtml?c=76046&p=irol-newsArticle&ID=1102838&highlight=>

⁷ News release, "Ballard Announces Third Quarter 2007 Results" November 7, 2007, accessed on website, March 26, 2008, <http://phx.corporate-ir.net/phoenix.zhtml?c=76046&p=irol-newsArticle&ID=1074511&highlight=>

⁸ News release, "Exide Technologies Signs Agreement With Ballard Power Systems for Forklift Truck Power Solution", October 9, 2007, accessed on website, March 26, 2008 <http://phx.corporate-ir.net/phoenix.zhtml?c=76046&p=irol-newsArticle&ID=1060673&highlight=>

⁹ News release, "Ballard Signs Supply Agreement With Voller for Fuel Cell Auxiliary Power Units, October 16, 2007, accessed on website, March 26, 2008 <http://phx.corporate-ir.net/phoenix.zhtml?c=76046&p=irol-newsArticle&ID=1063448&highlight=>

¹⁰ Globe and Mail, "Fuel Cell Firm Lays off Workers". Nov. 22, 2007.

According to industry analysts, this shift away from a research and development model to a self sustaining business model is a natural evolution and indicative of a maturing of the industry.

3. PROGRAM PROFILE

3.1 Program Information

3.1.1 Program Overview

The h2EA program started in the fall of 2003, and is scheduled to sunset in March 2008. The program was launched as part of the government's five year, \$215 million, Climate Change Plan for Canada, which initially allocated \$60 million for the h2EA program. \$10 million of this was allocated to the Canadian Transportation Fuel Cell Alliance (CTFCA) managed by NRCan to extend that program by two years.

In the period from 2003 to 2006, over 40 coalitions formally expressed interest in obtaining funding from h2EA. These distinct partnerships, given in Appendix D, represented 87 organizations, 39 of whom were firms constituting 60% of the Canadian h2 industry in 2003¹¹. Shifting government priorities and a review of expenditures in early 2006 led to a funding reduction for h2EA and the termination of spending on any new projects. At the time of this evaluation, the program had contracted six projects in total; one was terminated by mutual consent, one was inactive, and four became active. The four active projects represent over 50 companies, ranging from technology providers to funding partners to end-users and secondary suppliers, and cover a wide range of technologies and applications. In total, \$20.5 million was committed to h2EA projects as indicated in Table 2.

Table 2: h2EA Program Investments

Project Name	Investment	Consortium Participants
Hydrogen Solution for Utility Vehicles	\$4.25 million	Hydrogenics Corporation, Deere & Company, Hydrogenics Test Systems Inc., Emerson Network Power Canada
Stationary Fuels for Residential Heating and Power Generation	\$935,000	Fuel Cell Technologies Ltd., Ontario Power Generation Inc., and the University of Toronto at Mississauga
H2ICE Shuttle Bus Demo	\$4.2 million	Ford Motor Company of Canada Limited and Advanced Technologies and Fuels Canada Inc.
Integrated Waste Hydrogen Utilization Project	\$6.0 million	Sacré-Davey Innovations Inc., Sacré Consultants Ltd., Westport Innovations Inc., Westport Research Inc.
PEI Wind-Hydrogen Village Project*	\$5.1 million	Hydrogenics Corporation and Prince Edward Island Energy Corporation.

* This project has not proceeded and therefore was not included in this study.

¹¹ Key Performance Indicators, h2EA Program, February 20, 2007

3.1.2 Program Objectives

The transition to a hydrogen economy presented a unique opportunity for Canada, and in launching the h2EA program, it was intended that, in addition to progressing towards a sustainable solution to climate change, Canadian industry obtain a first-mover advantage, thus maximizing the benefits of this transition for Canadians. In accelerating the market acceptance of hydrogen and hydrogen-compatible technologies, approved h2EA projects were expected to provide broad environmental, economic and social benefits for all Canadians. Specifically, the strategic objectives of the h2EA program were to demonstrate:

- Integration of hydrogen and hydrogen-compatible technologies;
- Development of hydrogen infrastructures;
- Development of skills and the supply chain in the hydrogen industry;
- Development of codes and standards for the hydrogen industry;
- Increased performance, reliability, durability and economical viability of hydrogen and hydrogen-compatible technologies; and,
- Increased public, consumer and investor awareness and acceptance of the hydrogen capability.

3.1.3 Program Eligibility

Eligible activities for h2EA program funding were those that demonstrated the application of individual technologies and their integration into a comprehensive working complex of a hydrogen economy in Canada, including:

- All types of fuel cells;
- Fuel cell systems;
- Other hydrogen-based power-generation technologies and materials;
- Technologies and materials for producing, storing and distributing hydrogen from renewable and non-renewable energy sources; and,
- Working prototypes of portable, stationary, mobile and fuelling applications using hydrogen technology.

Eligible firms were required to participate in a group of legal entities consisting of two or more for-profit or not-for-profit incorporated entities, partnerships, cooperatives, trusts, associations or individuals. These firms needed to select one member of their group to be the point of contact with the government and to be the entity managing the contribution agreement. This lead eligible recipient had to be a Canadian company. In addition, each firm in the consortium was subject to all the terms and conditions of the contribution agreement, and was jointly and severally liable with all consortium members.

3.2 Project Information

Phase 1 Projects (completed/nearly completed in FY 2006 – 2007)

3.2.1 Hydrogen Solution for Utility Vehicles (identified throughout this report as the Hydrogenics Project)

This multi-year, \$10.05 million project, with an investment of \$4.25 million from h2EA and located at the Canadian National Exhibition (CNE) in Toronto, was led by Hydrogenics Corporation and includes a consortium of the following companies and organizations:

- Project Lead: Hydrogenics Corporation
- Consortium Members: Deere & Company, Hydrogenics Test Systems Inc., Emerson Network Power Canada
- Supporters: Purolator Courier, City of Toronto, Toronto Renewable Energy Co-operative, Hydrogen and Fuel Cell Canada, Interlink, and Bell Canada.

The objective of the project was to demonstrate the feasibility of a renewable energy-based refuelling station, showcase the technical capabilities of fuel cells and electrolyzers, and catalyze the growth of the industry in a manageable environment. The project was also expected to contribute to increased awareness and acceptance of hydrogen and hydrogen-based technologies as a fuel solution for the future. The project, which concluded on March 31, 2007, comprised four components:

(i) Fuel Cell-Powered Utility Vehicles - four fuel cell-powered utility vehicles operated in two phases (2005 and 2006). The project demonstrated on- and off-board diagnostics and monitoring equipment, including fuel cell degradation and depletion monitors, gas leak detection and performance database software.

(ii) Refueling Station - fueled by wind energy from the CNE wind turbine, production of about 65 kilograms of hydrogen per day by the station electrolyzer.

(iii) Back-up Power Generator for Telecommunications – demonstration of a fuel cell-powered module using compressed hydrogen, and a back-up system at the Interlink data centre.

(iv) Hybrid Fuel Cell/Battery Delivery Vehicle – demonstration of a hybrid fuel cell/battery delivery vehicle, and refueling station.

3.2.2 Stationary Fuels for Residential Heating and Power Generation (identified throughout this report as the FCTL Project)

Bringing together technologies and resources from all partners (see below), the \$1.87 million project, with an investment of \$935,000 from h2EA and led by Fuel Cell Technologies Limited (FCTL), showcased the use of four 5kW solid oxide fuel cells (SOFCs), arranged in mini-grid

configuration to provide electricity and heating to a 12-unit student residence at the University of Toronto at Mississauga (UTM).

Consortium members are as follows:

- Project Lead: Fuel Cell Technologies Limited
- Consortium Members: Ontario Power Generation Inc., University of Toronto at Mississauga
- Suppliers: Enbridge, Air Liquide Canada

Defined by two distinct phases, the project's initial task included a system design, a site evaluation and an implementation study. The second phase involved the installation of four fuel cell systems to supply the UTM residence electrical and heating grid. These were initially fueled by natural gas, but subsequently one of the four fuel cell systems was converted to hydrogen for the last six months of the project. Due to some delays, the project was extended from the project termination date, March 31, 2007, to June 30, 2007.

In addition to economic and environmental benefits, the project provided an educational resource for university students who monitored the heating and electrical systems. Operating under a number of seasonal and situational conditions, the installation allowed students to assess the systems' effectiveness, identify operational concerns and even implement modifications as required.

The installation has remained at the residence following the demonstration phase providing a long-term electrical and heating solution. It is expected that this will result in potential efficiencies and cost-savings for the UTM residence facility, and increase public awareness and acceptance of these technologies in residential applications.

Phase 2 Projects (projects completed in FY 2007-2008)

3.2.3 Hydrogen Internal Combustion Engine Shuttle Bus Demonstration (identified throughout this report as the Ford Project)

Ford of Canada and Advanced Technologies and Fuel Cells Canada Inc. (ATFCAN) have partnered to demonstrate ten Ford hydrogen-powered internal combustion engine (H2ICE) shuttle buses in four locations in Canada; three buses on Parliament Hill which are operating as part of the Senate's regular bus fleet, two buses in Vancouver operated for community groups by Sacré-Davey, three buses in Toronto operated by the City of Toronto, and two buses in PEI operated by the government of PEI. On Parliament Hill, the project has benefited from a hydrogen refueling station for the buses, which is being supplied by Air Liquide of Canada and funded in part by NRCAN. The buses are contracted to run from December 2006 to March 2008. The h2EA investment in the project amounts to \$4.2 million (approximately 50% of the \$8.5 million project cost).

The consortium members are:

- Project Lead: Ford of Canada
- Consortium Members: ATFCAN
- Suppliers: Dynetek, Les Entreprises Michel Corbeil
- Supporters: Senate of Canada, Sacré-Davey, City of Toronto, Government of PEI

3.2.4 Integrated Waste Hydrogen Utilization Project (identified throughout this report as the Sacré Davey Project)

This three-year project, led by North Vancouver-based Sacré-Davey Innovations Inc., received a contribution of \$6.0 million from h2EA¹².

The project, composed of seven demonstrations that will be implemented and demonstrated through 2008, makes use of an existing but currently untapped source of hydrogen fuel, hydrogen emitted as the by-product of a sodium chlorate manufacturing plant in the North Vancouver area. The project components include:

- Securing a source of hydrogen from a sodium chlorate manufacturing plant;
- Demonstrating a compressed hydrogen storage and transportation system;
- Demonstrating a hydrogen fuelling station for light-duty vehicles;
- Demonstrating a hydrogen and natural gas blend fuelling facility for heavy-duty vehicles;
- Demonstrating eight hydrogen-powered light-duty pickup trucks;
- Demonstrating four transit buses that use a blend of hydrogen and natural gas fuels; and
- Demonstrating a fuel cell system that will provide electrical power and heat to an environmentally friendly car wash.

The North Vancouver fuel station is one of the key stops on the BC Hydrogen Highway that will play a role in sustainable transportation demonstrations for the Vancouver/Whistler 2010 Olympic and Paralympic Winter Games.

Consortium members are:

- Project Lead: Sacré-Davey Innovations Inc.
- Consortium Members: Sacré-Davey Engineering, Westport Innovations Inc, Westport Research Inc.

¹² While at the time of the evaluation, the level of funding provided was \$6 million, subsequent amendments to the agreement have resulted in a decrease in funding to \$5.4 million.

- Suppliers: Clean Energy Fuels Canada Ltd., Dynetek Industries Ltd., Hydrogen Technology and Energy Corporation (HTEC), Nuvera Fuel Cells Ltd., Powertech Labs Inc., QuestAir Technologies Inc.
- Supporters: Easywash Inc., Translink, SDTC, Hydrogen Highway.

4. FINDINGS: RELEVANCE

Relevance was assessed against two criteria:

- Alignment with industry needs
- The extent to which the industry has evolved since the program was created

4.1 Alignment with Industry Needs

Conclusion

The h2EA program was seen by government and industry representatives as being in line with industry needs when it was established in 2003.

Findings

The program was a response to the Commercialization Road Map for Fuel Cells of 2003¹³ that identified challenges to commercialization and how to overcome them, including stimulating market demand through demonstration projects. Demonstrations were recognized as an important part of the innovation cycle; they allowed companies to test concepts and returns on R&D to enable a transition to the next steps in the evolution of the technology. In fact, many countries involved in fuel cell development, in addition to Canada, have such programs to reduce risks and validate the technology.

H2EA and CTFCFA have been the only federal government demonstration programs to focus on hydrogen; h2EA was, therefore, viewed as playing an important role in the sector's development. Evidence from the document review and interviews indicates that demonstrations have been necessary to help accelerate market adoption and validate the technology, particularly for early niche market fuel cell applications in areas such as mobile phones and handheld devices, back-up power systems, buses and forklifts.

4.2 Evolution of the Industry

Conclusion

The industry has evolved substantially since the program was created in terms of technological and industrial developments including the achievement of some commercial successes. Organizations within the industry, however, have evolved at different rates, and as a result there are diverging views on how best to support the industry's continued development.

¹³ Canadian Fuel Cell Commercialization Roadmap, Government of Canada, Fuel Cells Canada, PricewaterhouseCoopers, March 2003

Findings

Though the industry is widely considered by interviewees to have evolved since 2003, it has not done so evenly. In several respects, there have been important technological and industrial developments and even some signs of commercial success to which h2EA is considered to have been an important contributor. Hydrogenics' sales of back-up power systems is one such example of a smaller application of products/technologies demonstrated in the program. This development has helped Hydrogenics realign itself along a more sustainable business model that is manufacturing-focused as opposed to R&D-focused. Other developments have been in hydrogen infrastructure where there are now ten fuelling stations installed as part of the hydrogen highway and hydrogen village projects. Also, the clustering of end-users, developers and suppliers created by the demonstrations along with the strengthening of Hydrogen & Fuel Cells Canada have been pointed to by interviewees as evidence of the positive nature of this evolution.

In other areas, however, further technological progress is needed. Hydrogen storage, for example, is one area that requires considerably more targeted research and development. Research is currently underway at the National Research Council (NRC) Institute for Fuel Cell Innovation on hydrogen storage in support of commercialization in the transport sector. Other solutions being developed include storage of hydrogen in hydride form. Cold weather start is a second example of areas requiring additional research. While proton exchange membrane (PEM) fuel cells can now operate at sub-zero temperatures, there continue to be significant challenges to fuel cell applications, including improvements to the power density, durability and cost of fuel cells¹⁴.

Such limits in current fuel cell technology have led to a shift in attitude in the Canadian industry away from the ideal of pure hydrogen applications of fuel cells to the use of fuel cell hybrids which can operate with smaller, and therefore less expensive, fuel cells, or to the use of hydrogen based internal combustion engines as demonstrated by the Ford project. The fact that hybrid fuel cell systems using batteries in automobiles, and fuel cells combined with gas turbines in stationary applications are now being pursued is a significant shift from the thinking of five years ago when, we were told by interviewees, these options were not being considered.

For many respondents, the industry is evolving more slowly than expected at the outset of h2EA. The financial status of most of the companies involved in fuel cells has diminished since 2003 as private sector investment has dropped, a situation that some believe is partly the fault of the industry itself, which oversold the development timeline. As a result, some companies now have difficulty in joining cost-shared programs. At the same time, other firms are moving closer to commercialization.

Given differences in the evolution of organizations within the industry, views are diverging on how best to support the industry's continued development. One view is that funds now need to be directed to infrastructure. Those holding that view tend to be larger players in the industry who have progressed from demonstrations and are focused on commercialization and the necessary

¹⁴ Ballard Power Systems Technology Road Map, May 15, 2006

R&D to address gaps and weaknesses identified in the demonstrations - they are further down the development path. While demonstrations were recognized as an important component of commercialization as they provide the ability to get technology to users operating in a real world market, some in the industry have moved on to deployment, emphasizing market development rather than demonstrations.

Another perspective is that the focus should be on a system of tax credits to support the promotion of the production and acquisition of hydrogen fuel, the adoption of technology, and the purchase of fuel cells on a per KW basis. According to proponents, market forces should be the key driver, allowing customer value propositions to pull forward applications on a competitive basis.

Finally, others see a need for R&D programs targeted to key barriers such as hydrogen storage, and the continuing use of demonstrations for applications such as the testing of larger vehicles prior to commercial use. The issues, in this instance, are the cost of fuel cells and the need for the development of a supplier group.

While differences of opinion exist on its rate of development and needs, the industry is seen as heading in the right direction as shown by significant cost decreases resulting from volume manufacturing to meet increasing numbers of orders, and an evident confidence in generating applications. The general view from industry and government interviewees is that industry will continue to need support in future years for demonstrations, and for research and development, although government is likely to play less and less of a role as the marketplace matures. Discussions continue among stakeholders on the future needs of the industry.¹⁵

¹⁵ See for example, "Towards a National Hydrogen and Fuel Cell Strategy: A Discussion Document for Canada," Government of Canada, 2006, <http://www.ic.gc.ca/epic/site/hfc-hpc.nsf/en/mc00057e.html>, accessed on February 22, 2008.

5. FINDINGS: SUCCESS

For the purposes of this evaluation, success was measured through a detailed examination of program experience at the project level. Case studies of the universe of funded projects were undertaken to assess success in four areas:

1. Technical and organizational learning
2. Commercial success
3. Codes and standards
4. Awareness and acceptance

5.1 Overall Conclusion

The original intent of the program was to fund a small number of projects that would demonstrate a wide range of fuel cell and hydrogen technologies in working complexes of the hydrogen economy. The number of projects funded is within the original estimates for the program; however, fewer demonstrations have been supported within these projects, reducing the range of developmental experience in hydrogen and fuel cell applications for the Canadian industry. While the original objectives to support the creation and development of a Hydrogen Highway in BC and Hydrogen Village in Toronto have not yet been fulfilled, progress has been made.

5.2 Technical and Organizational Learning

Conclusion

Most companies involved have experienced technical learning, and general improvements in their capabilities in hydrogen technology. The real world experience that demonstrations have brought is considered a vital learning experience and has in some cases allowed for organizational learning as well. The two larger, more complex projects have benefited from a greater degree of learning due to the wider range of technology demonstrated, than have the smaller projects.

Findings

In the Hydrogenics project, one of the main areas of learning was on the engineering side, where consortium members collaborated on the integration of their technologies. In this area, each demonstration led to application-specific successes and learning. In the case of the Deere utility vehicles, a key engineering challenge was to get an electric drive system that could be integrated with a fuel cell whose voltage varies depending on the load. Several significant improvements were made in the integration of the components in the second set, most notably, the use of simpler, and therefore less expensive, fuel cell and control systems.

In addition to the learning acquired through the integration of technology for specific applications, there were also important insights derived from observing the applications operating in the field. This learning is based not only on the technical data that is collected but also on customer perceptions. The demonstrations allowed Hydrogenics, for example, to understand the service requirements of both Original Equipment Manufacturers (OEM) and end-users, and what role Hydrogenics would play in supporting its product.

In the FCTL project, despite several technical difficulties with the solid oxide fuel cells, the demonstration using natural gas was a success, logging a cumulative total of 5,484 hours generating electrical power and averaging 70% availability in the two months following the opening. The fuel cell itself (i.e. the ceramic tube) proved reliable and the actual integration of the fuel cells into townhouses using the heat recovery and electrical systems was relatively straight forward from a technological standpoint.

The Ford project has resulted in minimal technical learning specific to hydrogen technology within the consortium. In addition to the fact that the consortium was limited to a single technology company, design and development of the buses was the responsibility of the US parent company, and all data on vehicle performance is being transmitted back to the Innovation Centre in Dearborn, Michigan.

The Sacré Davey project has made important advances in integrating hydrogen and hydrogen compatible technologies and in developing the requisite infrastructure. Indeed, it has thus far successfully demonstrated several technology solutions, including H2ICE and HCNG technology and fuel cells, all of which are competing options for lowering greenhouse gases. Translink's four HCNG buses, for example, are proving to have among the lowest emission levels of all its environmental buses now in service.

5.3 Commercial Success

Conclusion

Commercial success has been negligible for all but Hydrogenics, which, through its demonstration of a backup power system, was able to secure a large follow-on order from an American back-up power supply company involved as a contractor in the demonstration. Though commercial success has been limited, h2EA has advanced hydrogen technologies closer to commercialization through the demonstrations.

Findings

Of the five demonstrations conducted in the Hydrogenics project, the stationary applications have shown the strongest economic viability. The significant follow-on order of 500 fuel cell

units from American Power Conversion¹⁶, for example, is a direct result of the Interlink demonstration. Emerson Power Networks of Canada¹⁷ is also moving forward in the near term with a fuel cell product for its customers, based on its Bell Canada demonstration with Hydrogenics.

On the mobility side, commercial viability is further away than consortium members had initially anticipated due largely to technical limitations of hydrogen storage and cold climate operation. Despite these limitations, the utility vehicle demonstrations have allowed Deere and Co. to move towards commercializing the electric drive train for its vehicles which can later accommodate a fuel cell when the technology matures. The Gator demonstrations have led to follow on orders from other companies interested in developing their own fuel cell applications. The demonstration furthest away from commercialization is the fleet delivery vehicle, which in addition to similar technical limitations, is hindered by current economics. At current prices, savings associated with improved fuel efficiency of the technology are insufficient to cover the premium cost of the hydrogen fuel and vehicle.

The other three projects have not yet led to any commercial successes. With the closing of FCTL, any potential commercial success from that demonstration project will be limited. However, at the time of the evaluation, Siemens Westinghouse had been in contact with FCTL to discuss terms for the purchase of certain components of the system. In the case of Ford, follow on orders of the buses themselves will depend on the demonstration results, which are expected to be completed by December 2009, and on Ford's decision whether to continue further with manufacturing the vehicles. In the Sacré Davey project, a few companies are close to confirming follow-on sales of products developed for the demonstrations. Dynetek's PowerCubes have the potential for future sales and Westport's technology is attracting a lot of attention. HTEC also represents a degree of commercial success, having been established as a commercial venture to sell compressed hydrogen.

5.4 Codes and Standards

Conclusion

The demonstrations have shown overall that codes and standards have been less of a barrier than originally anticipated by many of the companies involved. All demonstrations succeeded in obtaining the necessary permits and approvals. The key challenge for many was in communicating with the various parties to show how the demonstrations worked and how safety concerns were addressed.

Findings

¹⁶ News release, "Hydrogenics Awarded Supply Agreement From American Power Conversion to Deliver Up to 500 Fuel Cell Power Modules for Backup Power Applications", August 10, 2006 accessed via website on March 26, 2008, http://www.hydrogenics.com/ir_newsdetail.asp?RELEASEID=207097

¹⁷ News release, "Emerson Takes on Fuel Cells as Telecom Power Backup Solution", May 7, 2007, accessed via website on March 26, 2008, <http://www.emersonnetworkpower.com/energysystems/news-events-2007-5-07-FuelCellPanel.asp>

One of the challenges common to each demonstration in the Hydrogenics project consisted of the approval process set by the various regulatory bodies. Given that each application had different operational contexts, the challenges were for the most part unique. In the case of Interlink, which located its hydrogen cylinders in a downtown building, approval required that its storage room be classified as ‘exterior to the building’. Bell’s back-up power system, on the other hand, was located outside, and was thus more in compliance with existing codes.

While the FCTL project did not have any direct impact on the revision of codes, it did show that hydrogen systems can be installed in compliance with existing regulations, in particular those of the National Fire Protection Association (NFPA). Key to navigating through the various codes was Air Liquide, which did all the consultations with authorities with respect to standards and codes and met with them to discuss their expectations. One of the successes, therefore, has been to demonstrate that the codes and standards need not be seen as a barrier.

The Ford consortium discovered that, with one exception, there were in fact far fewer code and regulatory issues than initially anticipated. Efforts, instead, were redirected to communication with first responders, the end-user community, and with other parties to educate on the safety of the hydrogen vehicles.

The Sacré Davey project had a similar experience to the other consortia in finding that it is able to work within existing codes, but with considerable effort in negotiating with the respective approval authorities. Contracts with suppliers required that the technologies being supplied be approved by the appropriate authorities. In general the large number of applicable codes and standards together with the unclear boundaries of jurisdictional responsibility, the novelty of the technology and the fuel itself imposed a quick and steep learning process on all those involved.¹⁸

5.5 Awareness and Acceptance

Conclusion

Awareness and acceptance of hydrogen technology has occurred at two main levels. The first is among officials and individuals directly involved in the demonstrations, including first responders (fire, police, ambulance etc.), technicians and mechanics and building managers. All demonstrations have reported important strides in advancing awareness at this level. At the broader level of public awareness, results have varied for a number of reasons, including: the level of public visibility of the demonstration, the degree to which the public has access to the demonstration sites, the number of outreach sessions undertaken, and the fact that two of the projects had not completed their demonstrations at the time of the evaluation.

Findings

Each of the demonstrations in the Hydrogenics project had an important impact on the overall acceptance of hydrogen as an energy source. Having the utility vehicles used on public grounds

¹⁸ Source: Sacré-Davey Progress Report June 2007.

and made a part of the CNE for three consecutive years has greatly enhanced exposure to hydrogen technology, increasing both the public's and vehicle operators' comfort with the idea of working with hydrogen. Similarly, the Purolator Van, having operated on standard inner city routes, received considerable attention from a curious public who often made requests to have the vehicle explained.

For the less public demonstrations, these also had an impact notably on the officials inspecting code compliance. In several of the projects, where approvals were required, fire marshals and other regulators became enthusiastic supporters of the projects once they came to understand how the systems work and once the code requirements were attended to. For the Purolator Van project, the demonstration had an impact within the company as executives came to understand and support the project once they saw the vehicle in operation.

The overall awareness of these projects has also been greatly enhanced through the Hydrogen Village which aims to raise awareness and break down barriers to markets for hydrogen, fuel cell and other relevant technologies within the GTA. While the concept of a Hydrogen Village had been discussed some time before the h2EA program was launched, it was only with h2EA funding that the concept was able to materialize. These projects helped showcase the concept while at the same time meeting federal government funding objectives and aiding Canadian companies in securing funding. While the demonstrations themselves have run their course, they continue to be advertised around the world at trade shows and conferences (40 presentations and 15 events up until October 2007).

The overall public awareness of the FCTL project has also been enhanced through the Hydrogen Village, which has, along with all the hydrogen projects in the GTA, continued to advertise it at trade shows and conferences. In addition, the demonstration has had an important impact on the university as well as local authorities, having been shown that it is indeed possible to introduce these systems, and having increased their familiarity with the use of hydrogen. Having the demonstration on a campus also gave important exposure to the technology.

Ford project demonstrations are yet to be completed, and therefore the project's impact on public awareness has still to fully register. However, positive feedback from demonstrations and some media attention and press releases from the various organizations involved suggest that impacts are being felt. The choice of Parliament Hill as one of the sites has generally been favourable for promoting awareness and acceptance given that it captures the attention of parliamentarians and is a major destination for tourists. Impacts, however, have been mitigated by sensitivities particular to the Hill which have lessened the publicity given to the demonstrations. Because Parliament can not be seen as favouring any one firm or technology, public outreach events have been limited, as has any advertising of corporate entities responsible for the technology.

Some Sacré Davey demonstrations have received a relatively high level of public exposure, such as EasyWash and the mobile applications. Sacré Davey for its part has produced several flyers on the project and given several talks internationally on the various elements of the demonstration. But while the companies involved have created their own press releases, and often more than one, advertising their involvement in the project, media attention as a whole has

not yet been strong. It should be noted however that the demonstrations have only recently begun.

6. FINDINGS: DESIGN, IMPLEMENTATION, AND COST EFFECTIVENESS

6.1 Program/Project Design

Conclusion

Participants agreed that collaborative arrangements are a key factor in technology and market development for the industry. They generally accepted the program requirement to establish a consortium; however, some noted they had been able to achieve a high level of technology development within the supply chain and with a broad range of firms in other projects without this requirement. The concept of the consortia was ultimately accepted by applicants, however, the liability clause, which was put in place in order to minimize the financial risk to the government, caused significant difficulties for some companies. The requirement for all members of the consortium to be joint and severally liable for the project was a financial risk that some companies were reluctant to accept.

While the consortium requirement and the related liability clause were put in place to both encourage program success and minimize the financial risk to government, the evaluation revealed other characteristics of the projects that also played a role in achieving results:

- *Project size:* The two larger projects with many demonstrations – the Hydrogenics and Sacré Davey projects - were better able to demonstrate results than the smaller, less complex projects.
- *Type of end-user:* The involvement of firms as end-users as opposed to institutions helped to showcase market applications, furthering the technology's development.
- *Lead firm situation:* Lead firms that were either on a sound financial footing or who had strong managerial skills tended to be in a better position to deal with the administrative requirements of the program.

Findings

The consortium requirement was intended in part to promote collaboration and learning within the supply chain, a goal which is widely lauded within industry. Collaboration allowed technology providers to work with suppliers and equipment manufacturers to ensure effective integration of their products. The consortia arrangement has also been a significant catalyst in lining up the supply chain, helping to bring together potential suppliers. This was important both from a technical standpoint where knowledge is shared up and down the supply chain and from a business standpoint where the projects have given the lead companies the opportunity to work out a business model with partners.

Firms that were not the lead but which did agree to be a part of the consortia typically did not behave differently than their contract-based counterparts. In other words, there were no

noticeable behavioral differences between firms in or out of the consortia; all conducted their activities according to their particular contribution. The scope of the projects, which went beyond the capabilities of any one firm, appeared to have a more important impact on collaboration goals than a rigid consortium requirement.

The other intent of the consortium requirement was to minimize the financial risk to the government in funding these projects. This was done through the inclusion of a liability clause. Most interviewees commented that the liability clause was desirable in principle to the extent that it underpinned the creation of a consortia approach; however, in practice, conformity to the clause proved difficult as it required each company in the consortium to agree to be responsible for the actions of the others. Companies feared a partner might go under and leave the others liable to make up the loss to the project. As a result of these difficulties, negotiations between companies and with the h2EA program took longer than originally anticipated.

While the consortium and liability requirements were created in order to minimize project risks and maximize project success, other characteristics of the project design were also identified as key elements. Supporting several applications in one project, as was the case for the Hydrogenics and Sacré Davey projects, fostered inter-firm learning within the supply chain. Several of the applications, for example, were faced with similar learning curves in the area of code compliance and technology integration. The benefits of experience in one application could be transferred to other applications, helping to improve the chance of success of the demonstration project. Similarly, the Sacré Davey project has thus far successfully demonstrated several technology solutions, including H2ICE and Hydrogen-enriched Compressed Natural Gas (HCNG) technology and fuel cells, all of which are competing options to lowering greenhouse gases.

The ability of the lead firm to deal with delays and provide the administrative support required to effectively manage the project was also revealed to be a key success factor in project implementation. FCTL consumed a considerable amount of their resources in carrying out their project. Ford Canada, who had invested a significant amount of time in project administration, also reflected on the difficulty smaller companies must face in managing such a project. Having had one consortium led by a consulting firm specialized in project management (Sacré-Davey) underscores further the heavy burden of managing such projects.

Of the four consortia funded by h2EA, the Sacré-Davey consortium stands out in three important respects. First it is led by a consulting company with expertise in project management, as opposed to a technology developer who may not have the same capacity to deal with the administrative aspects of the program. Second, it is the only consortium to leverage funds up to the maximum of 75% under Treasury Board stacking rules. This situation, while beneficial from a financial standpoint, also resulted in additional administrative work, as the company had to attribute contribution dollars to specific elements of each demonstration in order to ensure compliance with the terms and conditions of each program. Third, the consortium relies heavily on contractors – five of the nine non-consortium firms involved - to provide hydrogen technology solutions for the demonstration. All of these factors have been important to the outcome of the project.

6.2 Program Implementation

6.2.1 Reaching Target Firms

Conclusion

The program reached its intended target firms. These target firms (most of whom were SMEs, exceptions being Ford Canada, Deere & Company, Purolator Courier and Bell Canada) consisted of a full supply chain of technology providers, users and suppliers as well as supporting government organizations.

Findings

The h2EA RMAF¹⁹ indicates that, to be successful, the program must reach a range of firms and other organizations including those involved with hydrogen production, storage and distribution; development of hydrogen and hydrogen-compatible technologies; and users who will integrate hydrogen technologies into portable, stationary and mobile applications. Program data indicates that, in addition to the firms receiving funding through the program, another 37 consortia applied or expressed interest in the program. These consortia/partnerships represent 87 firms and organizations involved in the hydrogen and fuel cell sector in Canada.

Other organizations with an interest in having a successful h2EA program that promoted industry development included Canada's Hydrogen and Fuel Cell Committee, Hydrogen & Fuel Cells Canada, the NRC Institute for Fuel Cell Innovation, CTFCA and SDTC.

There were 20 different hydrogen applications demonstrated through h2EA involving over 50 companies representing all areas of the h2 industry noted above (the h2EA participants and their areas of interest are set out in the Key Performance Indicators²⁰). In addition, CTFCA was a funding partner in the Hydrogenics, Sacré Davey and the Ford projects. SDTC was also a funding partner in the Sacré Davey project.

6.2.2 Application Process

Conclusion

The mechanism of a competitive application process was viewed as appropriate by most successful applicants that were interviewed, but many, both successful and unsuccessful, found the process to be rigid and time consuming. Interaction between the sponsoring program and companies in a developing sector like hydrogen and fuel cells is important at all stages of the application process, from contracting to reporting on results. It was suggested that sufficient

¹⁹ Results Based Management and Accountability Framework (RMAF), h2EA Program, Industry Canada – Technology Partnerships Canada, 2003

²⁰ Key Performance Indicators, h2EA Program, page 5, February 20, 2007

resources at the departmental level were not available at the start of the program to deal effectively with the high level of uptake.

Findings

Many interviewees noted the widespread interest in the program at its launch and during the application process. This interest in the program generated a large number of applications (40 applications by February 16, 2004²¹). In a week, various companies sent in 10-12 proposals, and from these h2EA invited more detailed individual proposals. Overall, this was seen by these applicants as a good approach; they were given the impression that the program was highly competitive but with not enough money to go around. While these companies had no issue with the approach, they were concerned that program resources were insufficient to handle the load. The program was quickly oversubscribed and, with only three individuals working on the program at the beginning, the program had insufficient capacity to assess applications in a timely fashion.

The length of the application review process was expected to take between one and three months, but in practice took much longer, up to a year in some cases. An audit conducted in 2006 by Industry Canada notes that the length of the process was due in part to the information and documentation gathering from applicants²². This had repercussions for applicants from both a technological and a financial perspective. For projects that were technologically driven, by the time they were approved, the technology had on occasion advanced and the projects were no longer viable unless the technology was updated. An industry respondent commented, “The industry is fast moving and the TPC approval process did not keep pace”. In that instance, the approval process took a year, and, for business reasons, the company did not proceed, suggesting that if that time had been shorter, the company may very well have implemented the project. The delays also brought challenges in keeping consortium members committed to the demonstration and, in some cases, led to a change in partners and a consequent change in the cost sharing arrangements.

The ‘batching of proposals’ was also of concern to industry. TPC would allow proposals to be sent in at any time but would forward them in batches to the selection committee on specific dates posted on the website. This extended the length of the approval process for some projects and, according to some interviewees, undermined much of the momentum that was built up in the proposal stage among consortium members. On the other hand, from a due diligence perspective, this procedure was necessary in order for proposals to be compared to one another in a competitive and transparent process.

²¹ h2EA Six Month Progress Report, Performance Management Network Inc., Industry Canada, November 23, 2004

²² Program Audit of the Hydrogen Early Adopters Program, Audit and Evaluation Branch, Industry Canada, June 2006.

6.2.3 Due Diligence Processes

Conclusion

The h2EA program was generally considered to be too rigid in its development and application of procedures for an industry that is not yet fully mature and subject to rapid technological change. Terms and conditions of the program were appropriate for demonstrations of existing technologies (which was the intent of the program) but less so for those still undergoing development, which, while unanticipated, included some of the technologies demonstrated through the funded projects. The reassignment of files, necessitated by changes in staffing levels over the project lifecycles, further complicated the situation, resulting in difficulties in providing seamless support in the administration of the funded projects.

Findings

The program was run with an approval system similar to that of TPC's R&D program. As a result, the due diligence process, when applied to h2EA, did not consider the fact that demonstration projects were likely to require adjustments during the course of implementation. For example, once a project had already been approved, TPC could not make changes under their rules of procedure unless a request was made to amend the contribution agreement with justification that, for the companies, would further delay implementation of the project. Amendments to the contribution agreement involved the Program Services Board (PSB), an Assistant Deputy Minister level Committee in Industry Canada, a step that added to the complexity and consequent delays in implementation.

Other administrative issues that caused difficulties for the companies were the interpretation of eligible costs, ensuring stacking limits were adhered to, compliance with legislative requirements, and, as mentioned in section 6.1, the need to ensure that contributions coming from different sources could be traced to specific elements of the project. This situation became even more difficult to manage as program staff changes resulted in the reassignment of files during the course of the project lifecycle. As a result, new relationships between consortia members and program staff needed to be built, some of which had become strained due to the complexities of managing the projects.

7. CONCLUSIONS

Technology developers in Canada's hydrogen industry are typically small or medium-sized with insufficient resources to absorb heavy reporting requirements, lengthy negotiations or payment delays. In their view, a flexible and responsive program structure is needed to assist firms in achieving program objectives. At the same time, there is a need to ensure the exercise of due diligence. Given this situation, the following suggestions may be useful when considering the design of future programs:

- (i) The consortium model of inter-firm collaboration, which is typically reserved for pre-competitive research goals, is only one way to promote inter-firm collaboration. Basic contractual relationships can be very successful in promoting inter-firm learning and knowledge sharing within the supply chain, provided the projects are sufficiently large so as to be beyond the capabilities of any one firm.
- (ii) The intent of technology demonstration programs is to absorb part of the risk inherent in advancing new technologies towards commercialization. Project requirements and due diligence processes should be designed to reflect that intent.
- (iii) The level of development of the technologies being proposed for demonstration projects is critical to the achievement of program objectives. Terms and conditions that are appropriate for demonstrations of proven technologies in key market applications may be less so for technologies still undergoing development.

The Hydrogen Early Adopters (h2EA) program has sunset on March 31, 2008. As a result, the evaluation report does not contain any recommendations, and a management action plan from the program was not required. The management response indicated that the program concurs with the findings and conclusions of the evaluation.