

2016

Canadian Hydrogen and Fuel Cell Sector Profile

November 2016



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CANADIAN HYDROGEN AND FUEL CELL SECTOR PROFILE 2016

For more than a decade, the Government of Canada and the Canadian Hydrogen and Fuel Cell Association (CHFCA) have collaborated to develop an industry profile of the Canadian hydrogen and fuel cell sector. The profile is published annually in order to:

- Capture trends, growth and achievements for the Canadian sector.
- Offer insights into the current state of the sector.
- Provide valuable information for policy makers, investors and other stakeholders.

The 2016 profile was commissioned by Innovation, Science and Economic Development Canada (ISED) and the CHFCA and conducted by MNP LLP. The information presented in the profile was collected through a survey of Canadian companies, educational institutes and government agencies that were directly involved in hydrogen and fuel cell-related activities in 2015. The profile also includes select industry highlights that were prepared based on publicly available information and information provided directly by organisations that participated in the survey. All monetary results are presented in Canadian dollars.

Our thanks to all the organisations that contributed to the development of the Canadian Hydrogen and Fuel Cell Sector Profile 2016.

INTRODUCTION

The Canadian hydrogen and fuel cell sector is recognised as a global leader in the industry for pioneering new technologies and industry expertise. Increasing demand for clean energy products and solutions domestically and worldwide is generating opportunities and investments in a broad range of applications, including passenger vehicles, buses, trucks, trains/trams, ships and planes, stationary and back-up power, and material handling. Fuel cell technologies are being used to enhance the performance of clean energy systems by helping to balance fluctuations in energy loads. These technologies also play an important role in helping to grow the renewable energy sector in Canada and around the world. The sector is an important contributor to the Canadian economy and the development of clean, efficient and reliable energy alternatives.

THE INDUSTRY AT A GLANCE IN 2015

In 2015, survey respondents from the Canadian hydrogen and fuel cell sector reported:

Revenue of **\$220 million** | **\$125 million**
of revenue from product sales

\$84 million of revenue from the
provision of services

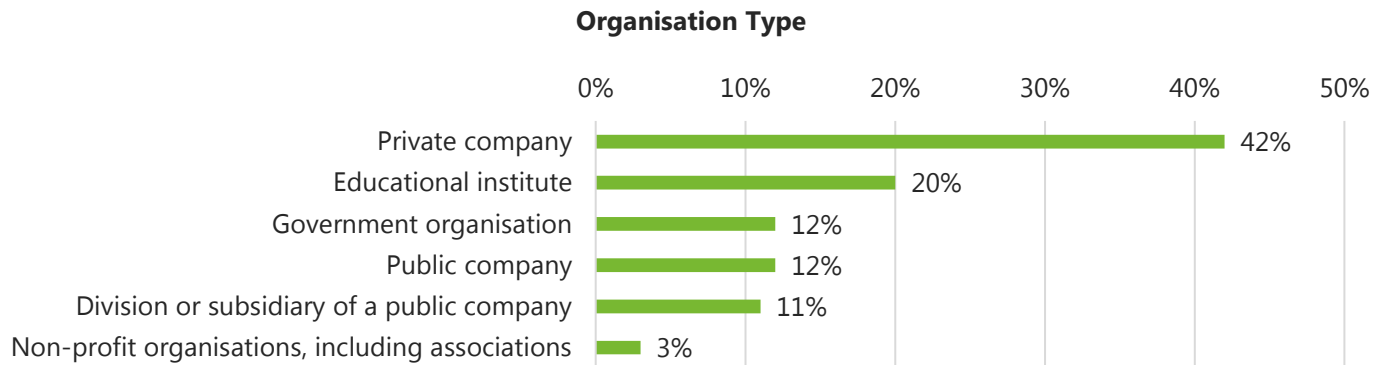
EMPLOYMENT of **1,785 jobs** | **OVER 18** **98** **222**
DEMONSTRATION PROJECTS | **STRATEGIC ALLIANCES** | **RESEARCH PARTNERSHIPS**

Research, development and demonstration expenditures of **\$173 million**

ORGANISATION PROFILE

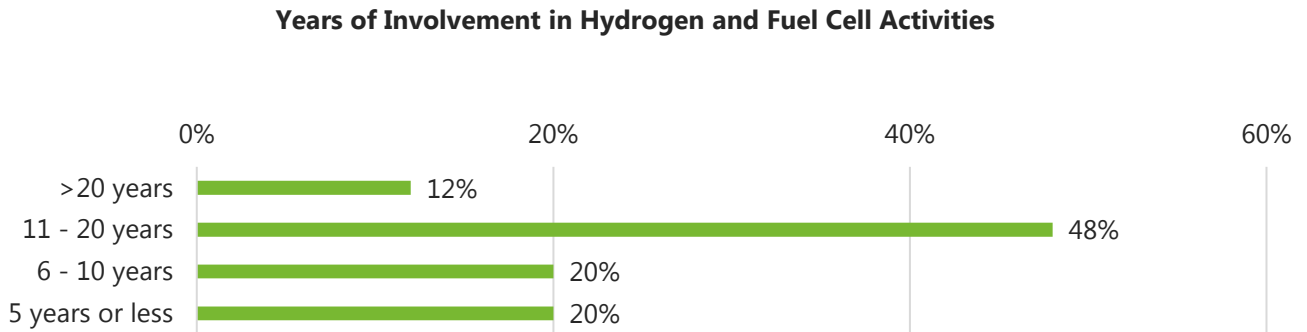
Organisation Type

Corporate organisations, including private companies, public companies and subsidiaries, represented 65% of total survey respondents. Government organisations accounted for 12%, and educational institutes and non-profit organisations, including associations, represented the remaining 23% of respondents.



Years of Involvement in Hydrogen and Fuel Cell Activities

The majority of survey respondents (60%) reported involvement in hydrogen and fuel cell activities for more than ten years.



Headquarters

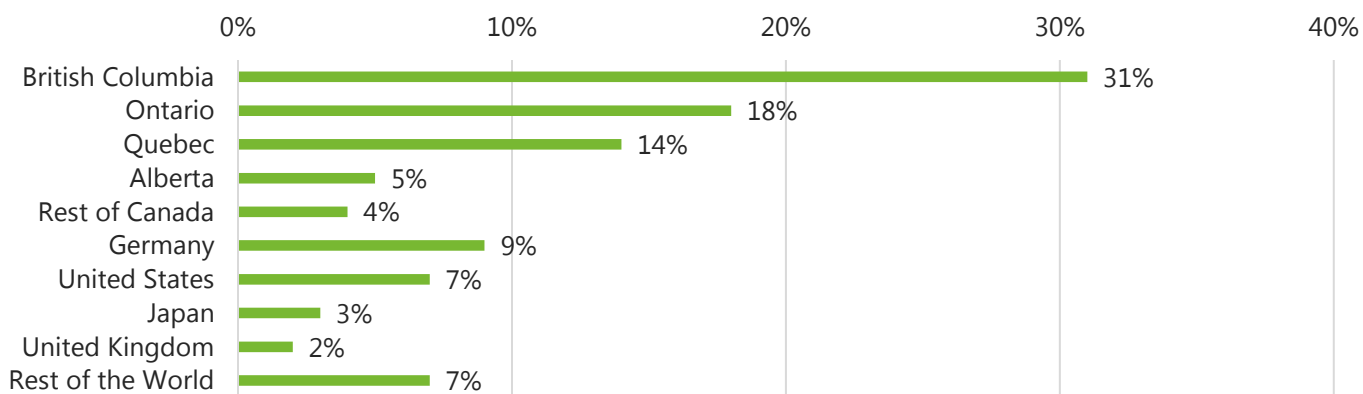
The companies surveyed all operate in Canada, with the majority of survey respondents (89%) reporting that their headquarters for hydrogen and fuel cell activities were located in Canada. Other survey respondents had headquarters in Germany, the United States, Japan, South Korea, and the United Kingdom.

Hydrogen and Fuel Cell Facilities by Region

Survey respondents reported 93 locations for hydrogen and fuel cell facilities and activities in 2015. In total, 72% of facilities were located in Canada, 9% in Germany, 7% in the United States, 3% in Japan, and 2% in the United Kingdom. The remaining 7% were in China, South Korea, Denmark, Belgium, France, India, and South Africa.

In 2015, hydrogen and fuel cell activities took place in most provinces within Canada. The majority of facilities and activities were in British Columbia (31%) and Ontario (18%), followed by Quebec (14%) and Alberta (5%). The rest of Canada (4%) included facilities in Manitoba, Newfoundland and Labrador, Nova Scotia, and Saskatchewan.

Hydrogen and Fuel Cell Facilities by Region

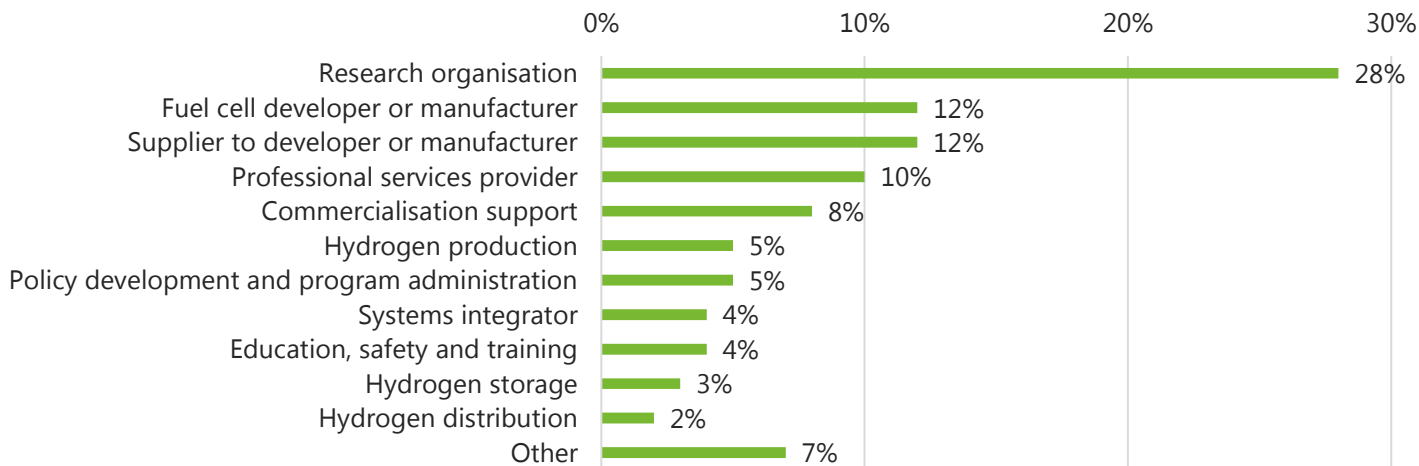


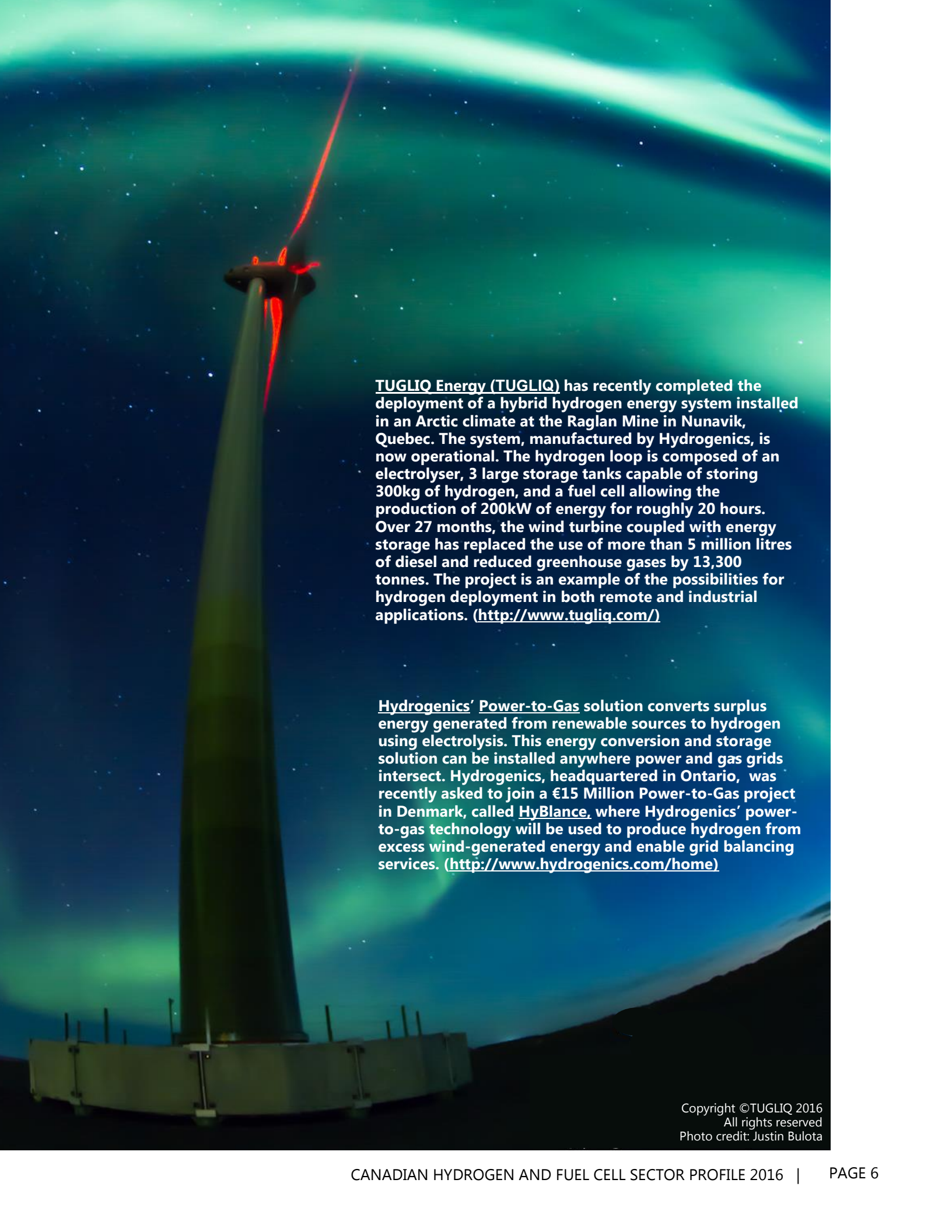
Areas of Expertise

Survey respondents' main area of expertise in 2015 was research (28%). Other areas of expertise included fuel cell development or manufacturing and supplying to developers or manufacturers (12% each), professional services (10%), and commercialisation support (8%).

Hydrogen production, policy development and program administration, systems integration, education, safety and training, hydrogen storage and hydrogen distribution each represented 5% or less of the survey respondents' expertise.

Areas of Expertise



A tall, slender wind turbine stands against a dark night sky. The aurora borealis, in shades of green and blue, dances across the upper portion of the frame. A bright red laser beam originates from the nacelle of the turbine and extends upwards into the sky. The base of the turbine is visible at the bottom, showing its concrete foundation and support structure.

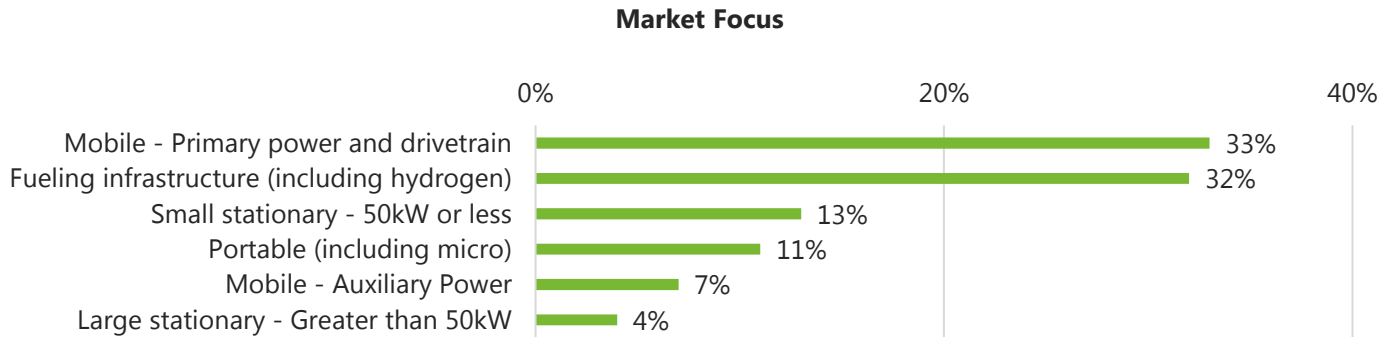
TUGLIQ Energy (TUGLIQ) has recently completed the deployment of a hybrid hydrogen energy system installed in an Arctic climate at the Raglan Mine in Nunavik, Quebec. The system, manufactured by Hydrogenics, is now operational. The hydrogen loop is composed of an electrolyser, 3 large storage tanks capable of storing 300kg of hydrogen, and a fuel cell allowing the production of 200kW of energy for roughly 20 hours. Over 27 months, the wind turbine coupled with energy storage has replaced the use of more than 5 million litres of diesel and reduced greenhouse gases by 13,300 tonnes. The project is an example of the possibilities for hydrogen deployment in both remote and industrial applications. (<http://www.tugliq.com/>)

Hydrogenics' Power-to-Gas solution converts surplus energy generated from renewable sources to hydrogen using electrolysis. This energy conversion and storage solution can be installed anywhere power and gas grids intersect. Hydrogenics, headquartered in Ontario, was recently asked to join a €15 Million Power-to-Gas project in Denmark, called **HyBlance**, where Hydrogenics' power-to-gas technology will be used to produce hydrogen from excess wind-generated energy and enable grid balancing services. (<http://www.hydrogenics.com/home>)

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Photo credit: Justin Bulota

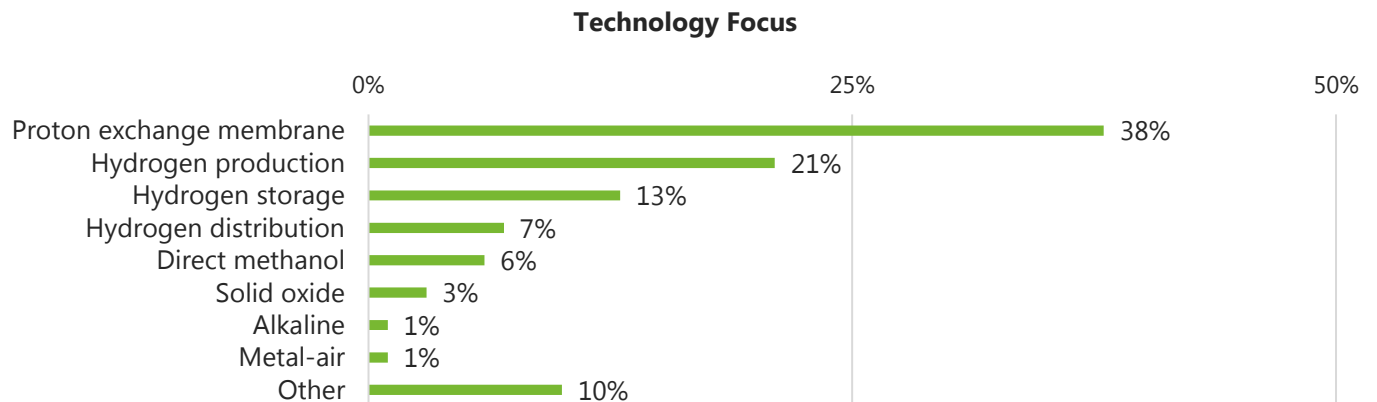
Market Focus

In 2015, the combined mobile applications of primary power and drivetrain (33%), portable (11%), and auxiliary power (7%), represented 51% of survey respondents' market focus. Fueling infrastructure, which includes hydrogen production, distribution, and storage, represented the second largest area of market focus (32%), while stationary applications accounted for the remaining 17%.



Technology Focus

Proton Exchange Membrane (PEM) fuel cells dominated the focus of survey respondents' technology activities in 2015 (38%). Together, hydrogen production, storage and distribution accounted for 41% of survey respondents' technology focus. Direct methanol represented 6%, solid oxide represented 3%, alkaline and metal-air each represented 1%, and other categories represented 10% of survey respondents' technology focus.



Powertech Labs' (Powertech) Advanced Transportation department, located in British Columbia, provides both high pressure testing and hydrogen infrastructure solutions. Powertech operates a comprehensive compressed hydrogen and natural gas testing facility able to test to all national and international test standards. Powertech also provides hydrogen fueling infrastructure products, such as hydrogen stations, hydrogen dispensers, and mobile fueling products. (<http://www.powertechlabs.com/home/>)



Hyundai and Mercedes-Benz fuel cell vehicles at Powertech fuelling station (Source: Mercedes-Benz Fuel Cells)



Greenlight Innovation, headquartered in British Columbia, has announced a new division that will focus on hydrogen infrastructure products. A dispenser for fueling fuel cell-powered light and heavy-duty vehicles has already been developed and the new division will provide tailored compression, storage and dispensing solutions. Greenlight Innovation also designs and manufactures fuel cell, electrolyser and battery pack test equipment, and provides automated assembly equipment for fuel cell, battery, and solar panel manufacturers. (www.greenlightinnovation.com/)

Greenlight Hydrogen Refueller (Source: Greenlight website)

REVENUE

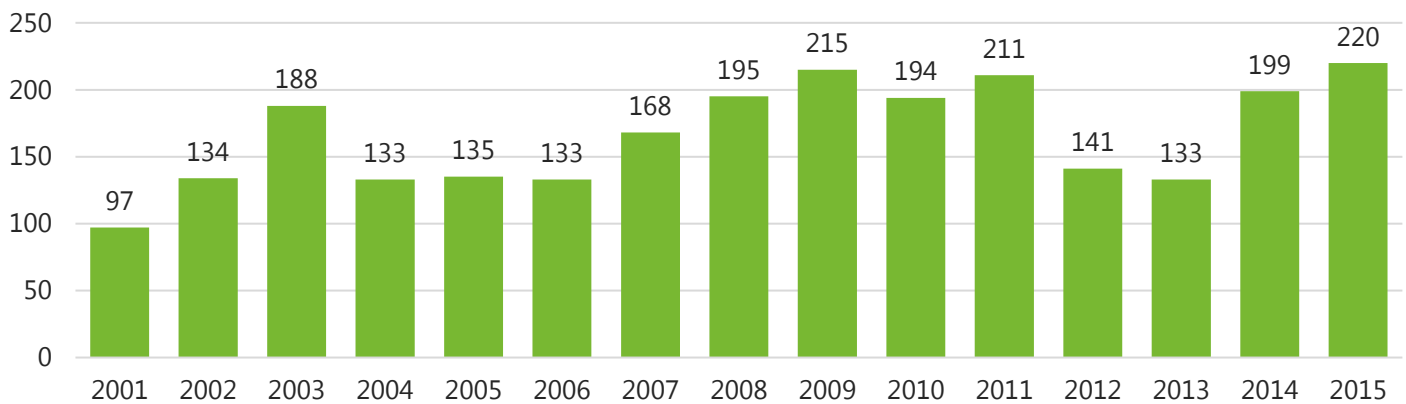
In 2015, 43% of survey respondents generated revenue from hydrogen and fuel cell activities, totalling approximately \$220 million. Year-over-year revenue is not directly comparable due to variations in survey respondents and participation rates.

Of the survey respondents that provided their revenue in 2015, 29% reported more than \$5 million in revenue, with about half of those respondents reporting revenue of more than \$25 million, 14% reporting revenue between \$1 and \$5 million, and 57% reporting less than \$1 million in revenue.

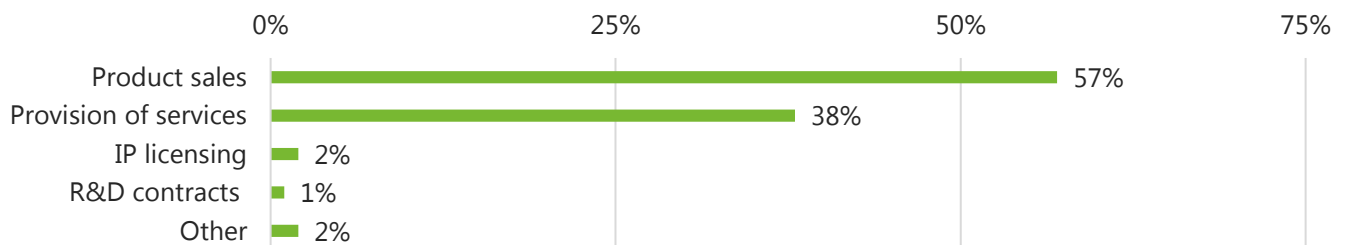
In 2015, survey respondents generated the most revenue from product sales and provision of services, which generated 57% (\$125 million) and 38% (\$84 million) in revenue, respectively.

The regions in which survey respondents generated the most hydrogen and fuel cell-related revenue in 2015 were the United States (33%) and Germany (31%). Overall, 3% of revenues were generated in Canada.

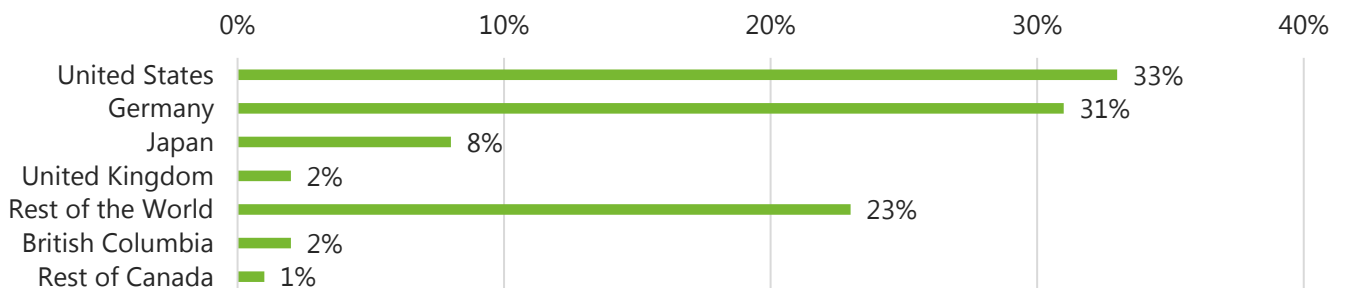
Revenue (\$ millions)



Revenue by Category



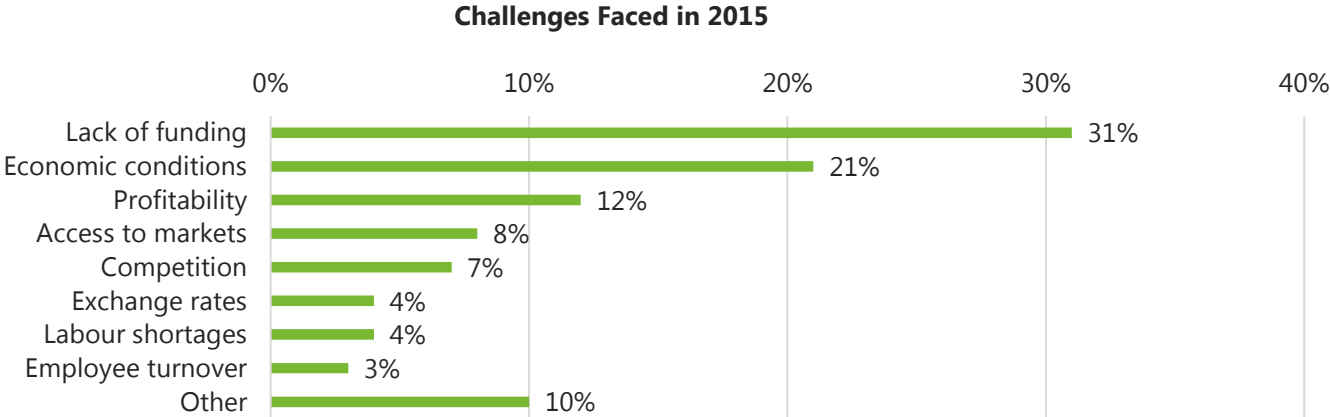
Revenue by Region



COMPETITIVE PERFORMANCE AND CHALLENGES

Survey respondents were asked to identify challenges faced by their organisations in 2015. The main challenges identified by survey respondents included lack of funding (31%), economic conditions (21%) and profitability (12%), followed by access to markets (8%) and competition (7%).

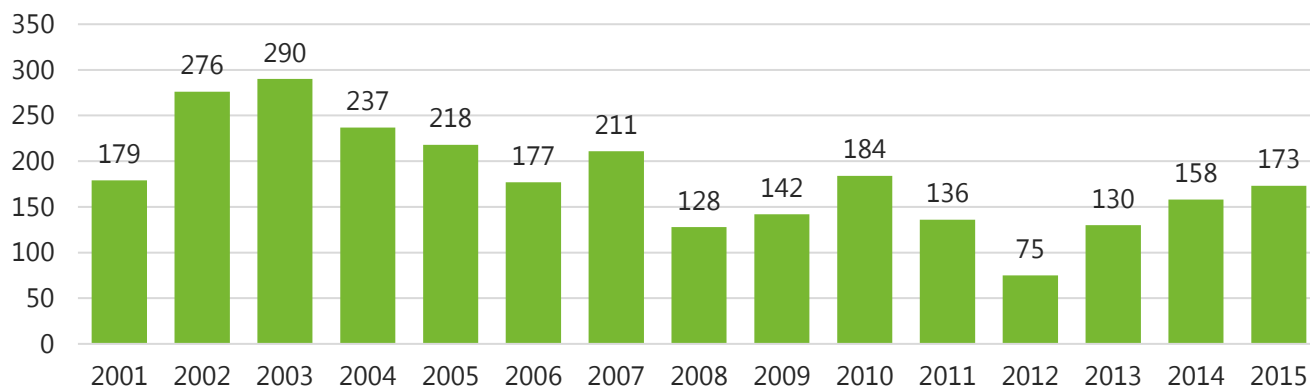
Respondents also reported exchange rates (4%), labour shortages (4%), and employee turnover (3%) as challenges faced in 2015. Other challenges identified by respondents were mostly related to a lack of market opportunities in Canada.



RESEARCH AND DEVELOPMENT (R&D) AND DEMONSTRATION

In 2015, 71% of survey respondents participated in research and development (R&D) and demonstration activities, reporting total expenditures of approximately \$173 million. Total R&D expenditure was \$171 million and demonstration expenditure was \$1.8 million.

R&D and Demonstration Expenditure (\$ millions)



2015 Total R&D and Demonstration Expenditure (\$ millions)

Type of Organisation	R&D	Demonstration	Total
Corporate	155.1	1.2	156.3
Government, Academic and Non-Profit	16.1	0.6	16.7
Total	171.2	1.8	173.0

Sources of Funding for R&D and Demonstration Expenditure

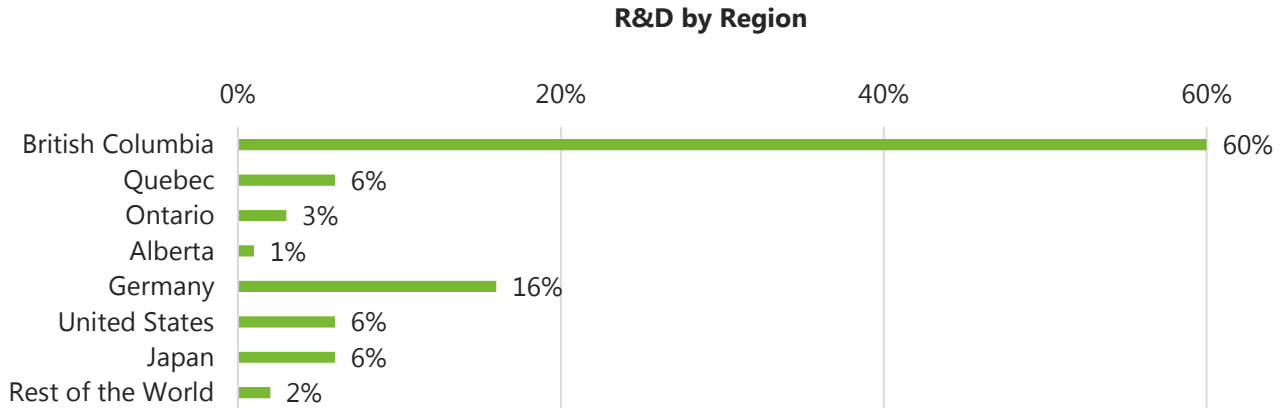
The table below provides a breakdown of survey respondents' funding for R&D and demonstration expenditures, by source. Corporate operations together with parent, affiliated or subsidiary organisations funded 86% of total reported R&D expenditures and 46% of reported demonstration expenditures.

Canadian governments funded \$19.8 million or 11% of R&D expenditures and \$0.7 million or 38% of demonstration expenditures.

2015 Source of Funding for R&D and Demonstration Expenditure	R&D		Demonstration		Total
	\$ millions	%	\$ millions	%	\$ millions
Parent, affiliated or subsidiary organisation	107.5	63%	0.1	6%	107.6
Corporate operations	38.7	23%	0.7	40%	39.4
Canadian government (all levels)	19.8	11%	0.7	38%	20.5
Foreign government	2.6	2%	0.0	1%	2.6
University or academic institute	1.5	1%	-	-	1.5
Other	1.1	0%	0.3	15%	1.4
Total	171.2	100%	1.8	100%	173.0

R&D by Region

Sixty percent of survey respondents' R&D expenditures took place in British Columbia, followed by Germany (16%). Six percent of respondents' R&D expenditures occurred in Quebec, 3% in Ontario, and 1% in Alberta, while the remaining R&D expenditures took place in the United States (6%), Japan (6%), and the rest of the world (2%).



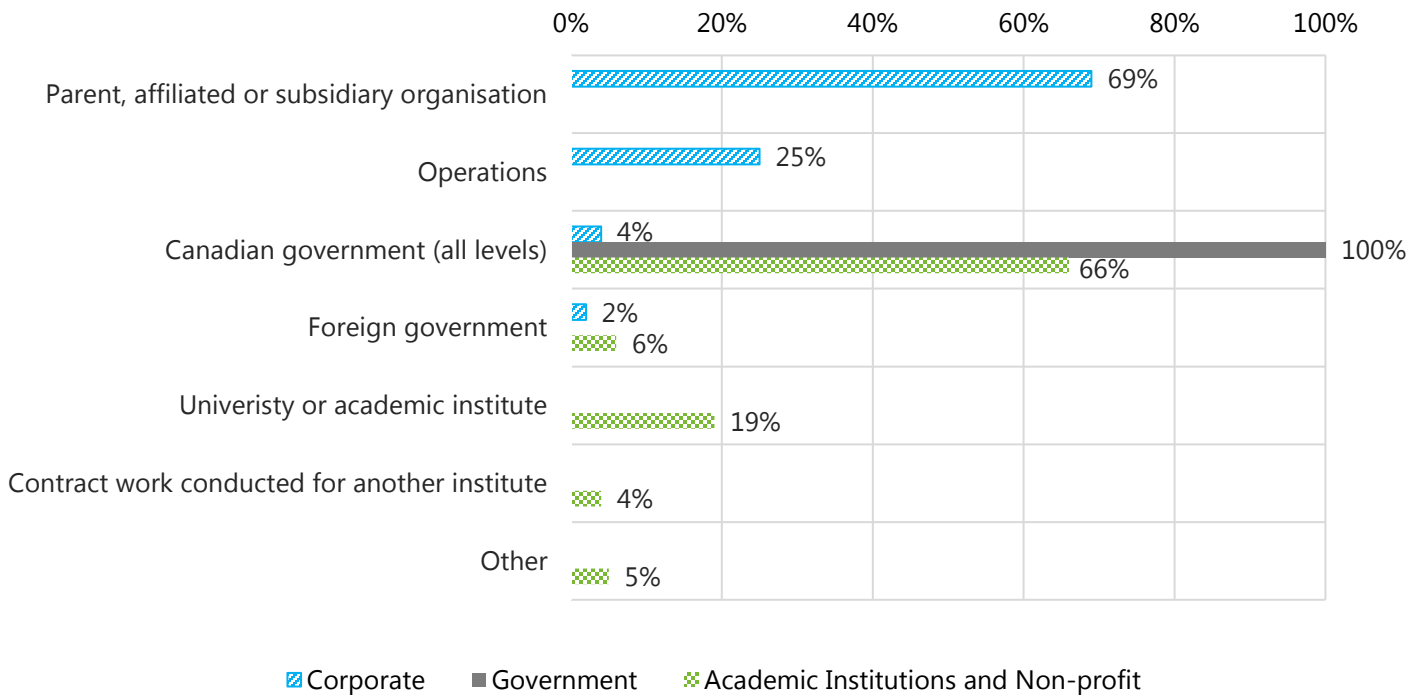
Lambton Energy Research Centre (LERC) is located at Lambton College in Sarnia, Ontario. LERC's Sustainable Smart House is a 1,700 square-foot, two-story, state-of-the-art research facility. It serves as an educational, testing and research facility for industrial partners pursuing research in renewable energy conversion, storage, and management and optimization technologies. The Sustainable Smart House is Lambton College's primary research hub in the area of hydrogen generation and storage and low-temperature fuel cells, including PEM, direct methanol and microbial fuel cells. Current research activities in collaboration with industrial partners include testing and optimization of a fuel cell-based combined heat and power (CHP) system for residential applications, and solar hydrogen generation utilizing doped titania nanotubes. https://www.lambtoncollege.ca/About_Us/Centres/Energy_Research_Centre/Home/

The Sustainable Smart House (top) and the Hydrogen and Fuel Cell Research Facility (bottom), which is located in the lower level of the Sustainable Smart House. (Source: Lambton College)

Sources of Funding for R&D Expenditure

In 2015, corporate survey respondents received the majority of their funding for R&D expenditure from parent, affiliated or subsidiary organisations (69%) and operations (25%). Government survey respondents received funding for R&D expenditure exclusively from Canadian government sources, while educational and non-profit respondents received most of their funding from Canadian government sources (66%), as well as universities or academic institutes (19%).

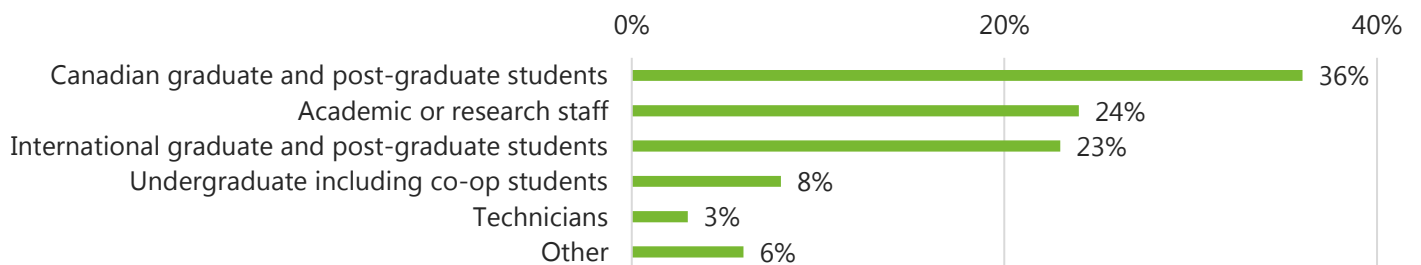
Sources of Funding for R&D Expenditures by Type of Organisation



People Involved in Research

Academic survey respondents reported that a total of 365 people were involved in hydrogen and fuel cell-related research activity in 2015. Of the total reported number of people involved in research, 36% were Canadian graduate and post-graduate students, 24% were academic or research staff, 23% were international graduate and post-graduate students, 8% were undergraduate students, including co-op students, and 3% were technicians.

People Involved in Research



Automotive Fuel Cell Cooperation (AFCC) is a research and development joint venture between Daimler AG (Mercedes-Benz) and Ford Motor Co. It is based in British Columbia and co-located with Mercedes-Benz Fuel Cell. AFCC's mandate is to improve the performance and reduce the cost of fuel cells produced by Daimler, Ford and other automotive customers. For instance, AFCC reduced its platinum use from 210 g in its GEN 2 fuel cell to 38 g in its GEN 3 fuel cell. AFCC is currently working towards the release of the GEN 4 fuel cell, which will be designed for high volume production, as well as further cost and platinum reduction. The GEN 4 fuel cell is being developed for the release of the 2017 Mercedes-Benz GLC fuel cell vehicle. (<http://www.afcc-auto.com/>)

Mercedes-Benz Fuel Cell (MBFC), located in British Columbia, is Daimler's global fuel cell manufacturing centre of excellence. It is the first automated fuel cell stack production facility of its kind in the world. MBFC's mandate is to determine how Daimler can manufacture fuel cell engines on an industrial scale and at an affordable price. (http://www.mercedes-benz.ca/content/canada/mpc/mpc_canada_website/en/home_mpc/passengercars/home/about_us/corporate_careers/areas_of_business.0003.html)



Mercedes-Benz GLC 2017 (Source: AFCC)

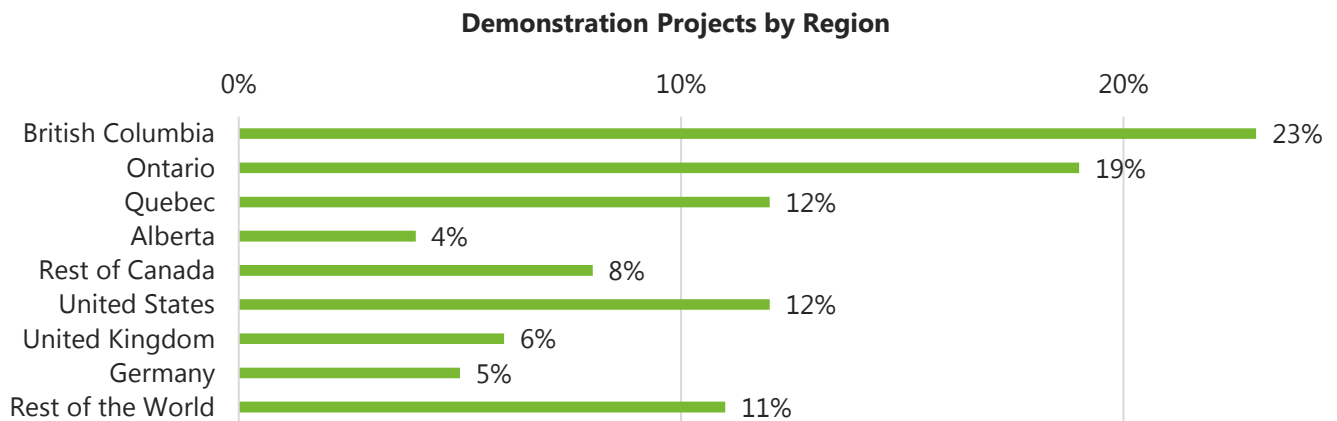
DEMONSTRATION PROJECTS AND PATENTS

Demonstration Projects

In 2015, survey respondents reported their participation in over 18 demonstration projects around the world.

Demonstration Projects by Region

Canadian provinces hosted 66% of survey respondents' total demonstration projects in 2015, the majority of which took place in British Columbia (23%). Other Canadian provinces accounted for 43% of demonstrations, which were hosted in Ontario (19%), Quebec (12%), Alberta (4%), and other provinces (8%). The remainder took place in the United States (12%), United Kingdom (6%), Germany (5%), and other countries (11%).

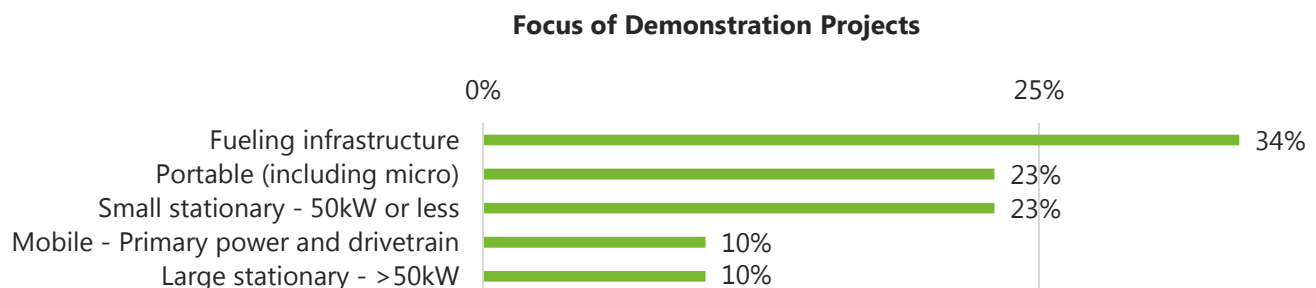


Sources of Funding for Demonstration Projects

In 2015, corporate operations funded 40% of the \$1.8 million in demonstration expenditure reported by survey respondents, while Canadian governments funded 38%.

Focus of Demonstration Projects

Survey respondents' main area of focus for demonstration projects was fueling infrastructure (34%), followed by stationary applications and mobile applications (34% each).



Patents and Licenses

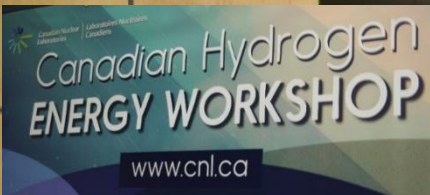
In 2015, survey respondents had access to 524 approved patents and licenses and had 135 patents pending.



Environment and Climate Change Minister Catherine McKenna, Transport Minister Marc Garneau, and Natural Resources Minister Jim Carr test drove a Toyota Mirai hydrogen fuel cell car in Ottawa, September 19, 2016. (Source: Transport Canada)

Transport Canada imported two Toyota Mirai fuel cell vehicles from California to perform environmental and safety testing. Test results will aid Transport Canada, Natural Resources Canada and Environment and Climate Change Canada in the development of codes, standards and regulations required to support the commercialisation of hydrogen fuel cell cars. Environmental testing will generate information about how fuel cell vehicles perform under Canadian operating conditions, including measuring range and performance in cold temperatures. Safety testing involves an evaluation to assess the integrity of the fuel system and how the vehicle performs in a collision.

Canadian Hydrogen Energy Workshop hosted by CNL in September 2015. (Source: CNL)



Since 2014, Canadian Nuclear Laboratories (CNL) has been involved in developing and commercialising hydrogen technologies for nuclear and non-nuclear applications, most of which directly relate to clean energy production and utilization. In September 2015, CNL hosted the Canadian Hydrogen Energy Workshop in Chalk River, Ontario. Over 40 industry and academic experts from across Canada took part in the workshop. Participants attended presentations by 17 invited speakers from across the sector and toured the hydrogen research facility to acquire an appreciation for CNL's hydrogen capabilities. (<http://www.cnl.ca/en/home/default.aspx>)



EMPLOYMENT

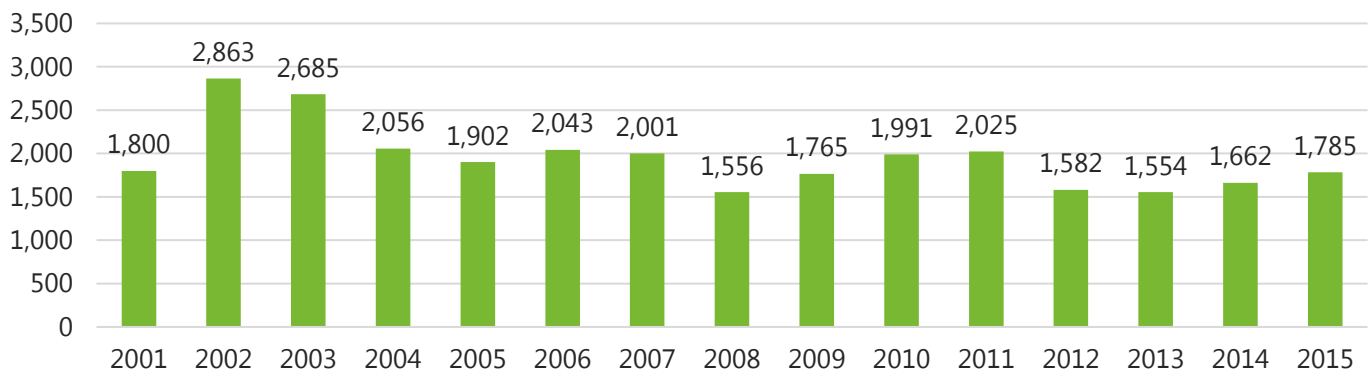
Survey respondents reported a total of 1,785 employees involved in hydrogen and fuel cell activities in 2015. Corporate organisations employed the majority of these employees (81%).

In 2015, the largest proportion of survey respondents' employees (approximately 81%) were located in Canada. Within Canada, most employees were located in British Columbia, followed by Ontario and Quebec. Other employees were in the United States (7%), Japan (4%), and Germany (2%). The remaining 5% were in other countries including, India, Thailand, Belgium, Denmark, and the United Kingdom.

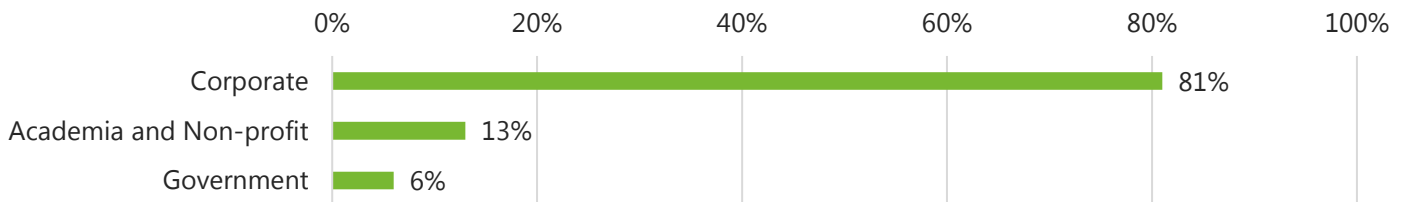
Most survey respondents (62%) had 10 or fewer employees. Thirteen percent had between 11 and 25 employees, 11% had between 26 and 50 employees, and 14% had more than 50 employees.

Based on the data provided by survey respondents for the number of employees and total salaries, the average annual salary paid to employees was \$66,315 in 2015. Extrapolating the average salary to the 1,439 employees reported in Canada, survey respondents contributed approximately \$95 million in salaries to the national economy.

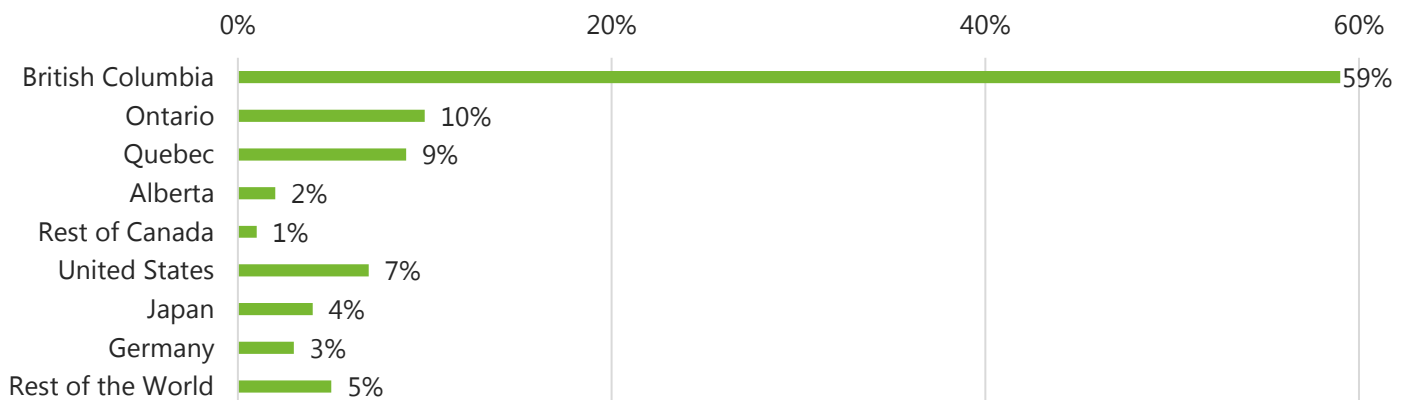
Employment



Employment by Sector



Employment by Region



RESEARCH PARTNERSHIPS AND STRATEGIC ALLIANCES

Research Partnerships

Research partnerships promote closer collaboration between the university research community, government, and industry. Survey respondents reported 222 research partnerships in 2015. Since survey respondents may report partnerships they have with each other, there is a possibility that the number of research partnerships is overstated. However, the distribution of research partnerships by type is expected to be representative of actual partnerships.

The number of research partnerships signifies the necessity of pre-commercial collaboration in order to address common technical challenges. The table below illustrates the various types of partnerships and collaborations reported by survey respondents in the hydrogen and fuel cell sector within Canada and abroad.

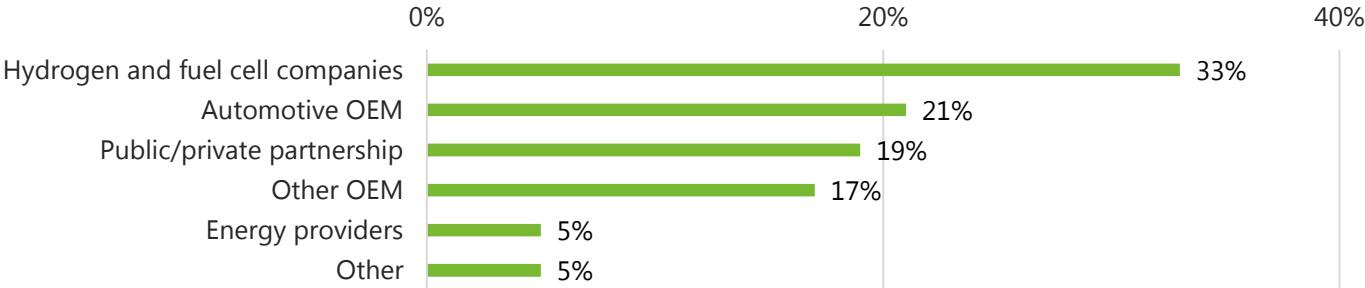
In 2015, partnerships with Canadian academia/non-profit/associations represented 27% of all reported research partnerships, followed by partnerships with industry in Canada (26%) and the Canadian government (13%). Partnerships outside the country, including partnerships with industry outside of Canada and foreign governments, represented 27% of reported research partnerships in 2015.

Research Partnerships	Number	%
Partnerships with Canadian academia/non-profit/associations	61	27%
Partnerships with industry in Canada	58	26%
Partnerships with industry outside of Canada	33	15%
Partnerships with Canadian government	28	13%
Partnerships with foreign governments	26	12%
Other	16	7%
Total	222	100%

Strategic Partnerships and Alliances

In 2015, survey respondents reported 98 strategic partnerships and alliances. Hydrogen and fuel cell companies represented 33% of these partnerships and alliances, while automotive OEM represented 21%. Public/private partnerships represented 19%, followed by other OEM (17%) and energy providers (5%).

Strategic Partnerships and Alliances





Canada is a key partner in the International Partnership for Hydrogen and Fuel Cells in the Economy (IPHE). The 18 IPHE partner economies have committed to collaboration in their efforts to commercialise fuel cell and hydrogen technologies. IPHE provides a platform for sharing and coordinating policies, applicable codes and standards. The IPHE steering committee meets twice a year to discuss developments in the fuel cell and hydrogen sector in partner economies. (<http://www.iphe.net/index.html>)

New Flyer Industries Inc. (New Flyer), which has operations in Manitoba and Ontario, is a leading transit bus and motor coach manufacturer and parts distributor in North America. New Flyer recently conducted a road demonstration of its **Xcelior® XHE60** heavy-duty 60-foot articulated fuel cell transit bus. The bus is targeted to have a range greater than 250 miles without refueling or recharging and a potential loading of over 120 passengers. New Flyer partnered with Ballard Power Systems and Siemens to develop the propulsion system for the bus. (<https://www.newflyer.com/>)



(Source: New Flyer news release)



(Source: New Flyer news release)

Dana Incorporated (Dana), a US based company with plants in Ontario, is a supplier of highly engineered driveline, sealing, and thermal-management technologies for both conventional and alternative-energy powertrains. Dana recently joined the **Project INSPIRE Consortium**. During this three-year project, Dana will work with major European companies, including Johnson Matthey, SGL Carbon and the BMW Group, to try to validate the next generation of automotive fuel cell stack technology and accelerate the commercialisation of high performance, zero emission, fuel cell electric vehicles. (<http://www.dana.com/>)

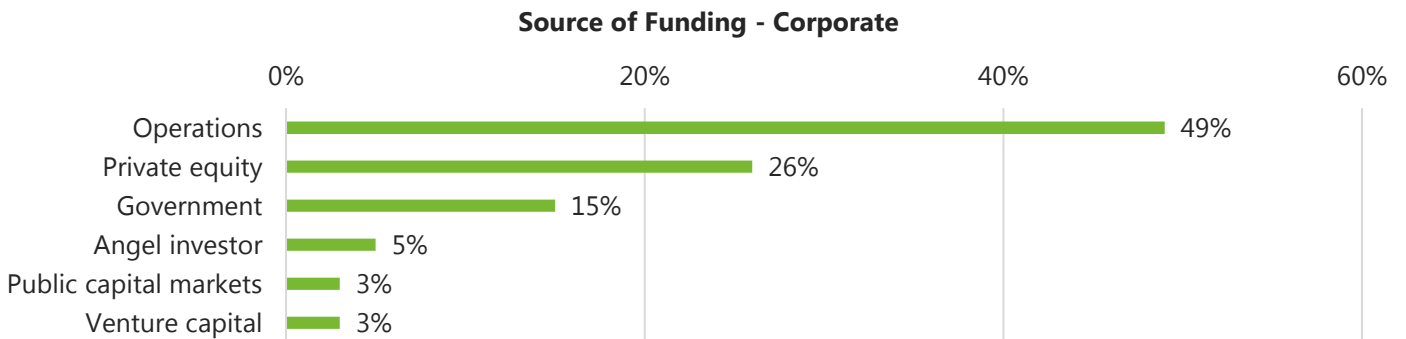
FUNDING REQUIREMENTS

Given the hydrogen and fuel cell sector's long development period and demanding R&D and demonstration requirements, adequate funding is necessary to bring commercial products to market.

Corporate

Corporate survey respondents reported the top three sources of funding for 2015 were from operations (49%), private equity (26%), and government (15%).

Corporate survey respondents estimated their financial requirements for the next five years to be approximately \$815 million.



Twenty-eight percent of corporate survey respondents reported new investment in the sector in 2015. The majority of new investments originated from the United States (34%), followed by Canada (30%). Within Canada, British Columbia and Quebec accounted for 19% and 9% of new investments, respectively, while other provinces represented 2%. The remaining new investment in the sector was from Japan (9%) and other international sources (27%).

Corporate survey respondents' main targets for new investment in 2015 were mobile applications, including primary power and drivetrain (33%), auxiliary power (11%), and portable applications (11%), followed by fueling infrastructure (17%) and stationary applications (28%).

Government

The total budget for hydrogen and fuel cell related activities reported by government survey respondents in 2015, for which they were directly responsible, was approximately \$3 million (including employee salaries and benefits). Programs contributed approximately 65% of the funding, while A-base operations represented the remaining 35%.

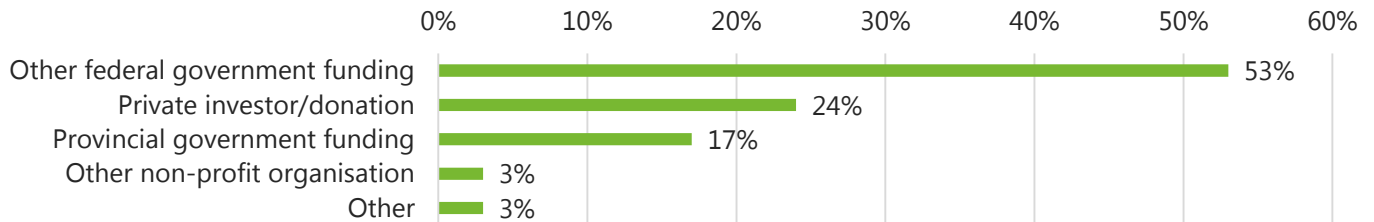


British Columbia is the first province to provide incentives for the purchase or lease of hydrogen fuel cell vehicles. The [British Columbia Ministry of Energy and Mines](http://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/clean-energy-vehicle-program) is responsible for the [Clean Energy Vehicle \(CEV\) Program](http://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/clean-energy-vehicle-program), which provides point-of-sale incentives of up to \$6,000 for the purchase or lease of a hydrogen fuel cell vehicle. A [Clean Energy Vehicle Economic Opportunities Assessment](http://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/clean-energy-vehicle-program) was recently completed for the province to help set the economic development context for the CEV Program and support policy direction going forward. (<http://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/clean-energy-vehicle-program>)

Academic and Non-Profit

The total budget for hydrogen and fuel cell related activities reported by academic and non-profit survey respondents in 2015, for which they were directly responsible, was \$9.9 million (including employee salaries and benefits). Federal government funding represented 53% of total funding, followed by private investors/donations (24%), provincial government funding (17%), non-profit organisations (3%), and other sources, including allocation through departmental budgets (3%).

Source of Funding - Academic and Non-profit

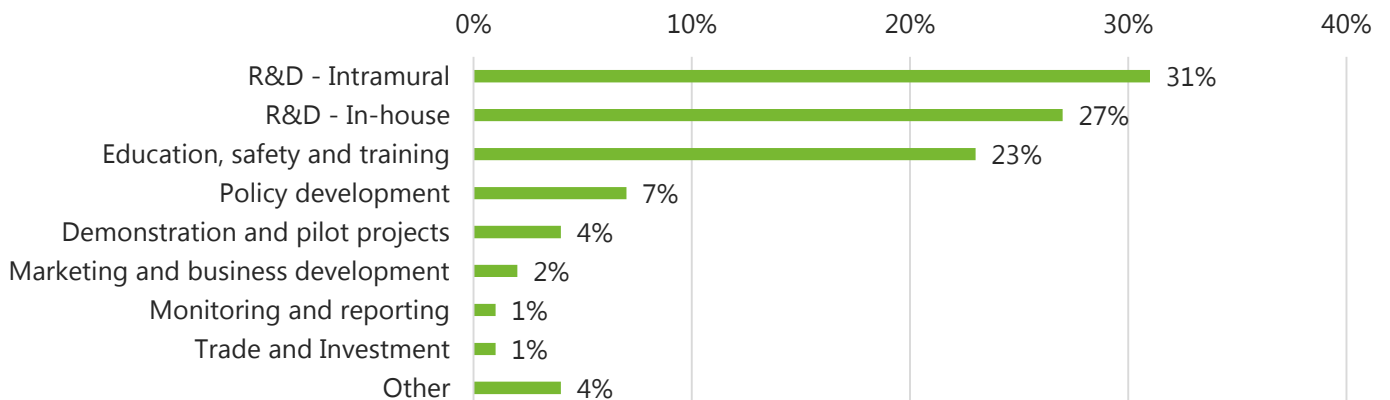


The **Canadian Hydrogen and Fuel Cell Association (CHFCA)** is a national, non-profit association that supports and represents the majority of the stakeholders in Canada's hydrogen and fuel cell sector. CHFCA has assisted member companies in identifying new markets, overcoming government regulatory hurdles, and connecting with international stakeholders. In collaboration with the Government of Canada, CHFCA hosted the annual international Hydrogen + Fuel Cells Summit. The next summit will take place in Vancouver, BC on June 5-6, 2017. (<http://www.chfca.ca/>)

Government, Academic and Non-Profit

In 2015, government, academic, and non-profit survey respondents collectively allocated over half of their funding (58%) to R&D (both intramural and in-house). Twenty-three percent of funding was allocated to education, safety and training. Separately, educational institutes and non-profit respondents allocated 67% of funding to both intramural and in-house R&D and 29% to education, safety and training, while government respondents allocated 29% of funding to policy development, followed by in-house R&D (27%) and demonstration projects (16%).

Funding Allocation By Area - Government, Academic and Non-profit





Woodside Hydrogen Production and Fuelling Station (Source: HTEC)

Hydrogen Technology & Energy Corporation (HTEC), located in British Columbia, specializes in the production, distribution, and dispensing of hydrogen, including the design and installation of hydrogen refuelling stations. HTEC is nearing completion of its first public hydrogen vehicle fueling station, which is located in Woodside, California. The station is supported by the California Energy Commission and is part of the Silicon Valley sub-network of hydrogen stations. HTEC will own and operate the *Skyline Hydrogen Energy & Education Center*, which will provide fuel, as well as fuel cell vehicle and hydrogen training, education, and promotion activities. HTEC is also building a network of public fueling stations in British Columbia, with the first one set to open in the spring of 2017. (<http://www.htec.ca/>)

Ballard Power Systems (Ballard), based in British Columbia, is recognized as a leader in proton exchange membrane fuel cell development and commercialisation, and has had success in the Chinese market in recent years. In 2016, Ballard's FCveloCity®-HD fuel cell module was used in a tram demonstration in Hebei Province, China. The tram is powered by Ballard's fuel cell module along with super capacitors. According to Ballard, the tram is the first of its kind. Ballard also signed definitive agreements for the establishment of production operations in China, where its FCvelocity®-9SSL fuel cell stack will be packaged into fuel cell engines and integrated in zero-emission buses and commercial vehicles in China. Twenty-two Ballard fuel cell-powered buses have been deployed in the country. (<http://ballard.com/>)



Ballard-powered Tangshan Railway Vehicle tram during its demonstration in Hebei Province, China (Source: Ballard)



Ballard-powered Tangshan Railway Vehicle tram during its demonstration in Hebei Province, China (Source: Ballard)

Hydra Energy, headquartered in British Columbia, provides Hydrogen-as-a-Service by converting automobiles to a dual-fuel internal combustion engine system (hydrogen and diesel or gasoline). Hydra Energy offers its services to fleet operators of cars (e.g. taxi and corporate operators) and heavy duty trucks (regional haul) with return to base vehicles. Hydra Energy covers the cost of upgrading the vehicles and onsite refueling, and only charges for the sale of hydrogen on fixed-term fuel supply contracts. According to Hydra Energy, dual-fuel internal combustion engines offer the potential to cut operating costs via reduced fuel pricing, achieve emissions reductions that are comparable with fuel cell and hybrid vehicles, and have the benefit of being retrofit-compatible. (<http://www.hydra-energy.ca/>)

OUTLOOK

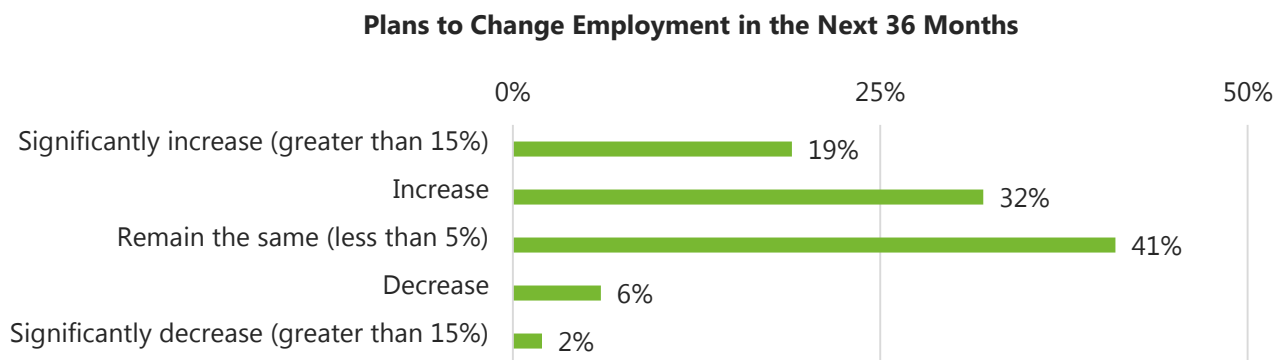
Looking ahead to 2016, survey respondents were asked to identify their top three priorities to enhance their competitive performance. Survey respondents' top priorities were technology development (26%) and collaboration and strategic alliances (23%). This was followed by cost reduction (14%), growing market share (8%), and expansion plans (8%).

Improving processes, better targeting of customers, better market or customer data, and staff reduction were also identified as priorities for some respondents, as were financing, infrastructure investment, and new knowledge generation.



Employment Outlook

Fifty-one percent of survey respondents planned to increase or significantly increase employment within 36 months, 41% planned to keep employment the same over the next 36 months, and 8% planned to reduce employment.



Handheld IR transmitter (HHT)
(Source: IRDI)



IRDI System (IRDI), headquartered in British Columbia, is a manufacturer of infrared communication equipment and other products used by the hydrogen and fuel cell industry. IRDI's protocol converter is the only equipment of its kind to be approved by the Japan Technology Institution of Industrial Safety. Furthermore, IRDI's handheld transmitter is the first of its kind and allows hydrogen fueling station integrators and operators to easily test the infrared communication system. Beta samples are in use by Toyota and Air Products, and shipments to Europe began in September 2016. (<http://irdisystem.com/>)



New Zolair Zinc Air Fuel Cell
(Source: Zolair)



Zolair zinc air fuel cells light up a rural home in India
(Source: Zolair)

Quadrogen Clean-up system in Orange County Sanitation District, California (Source: Quadrogen)



Zolair Energy (Zolair), headquartered in British Columbia, is focused on providing clean and affordable electricity to developing communities around the world. Along with on-demand electricity, Zolair provides wireless activation and pay-as-you go energy systems for communities. (<http://zolairenergy.com/>)



Quadrogen Landfill Gas Clean-up System (Source: Quadrogen)



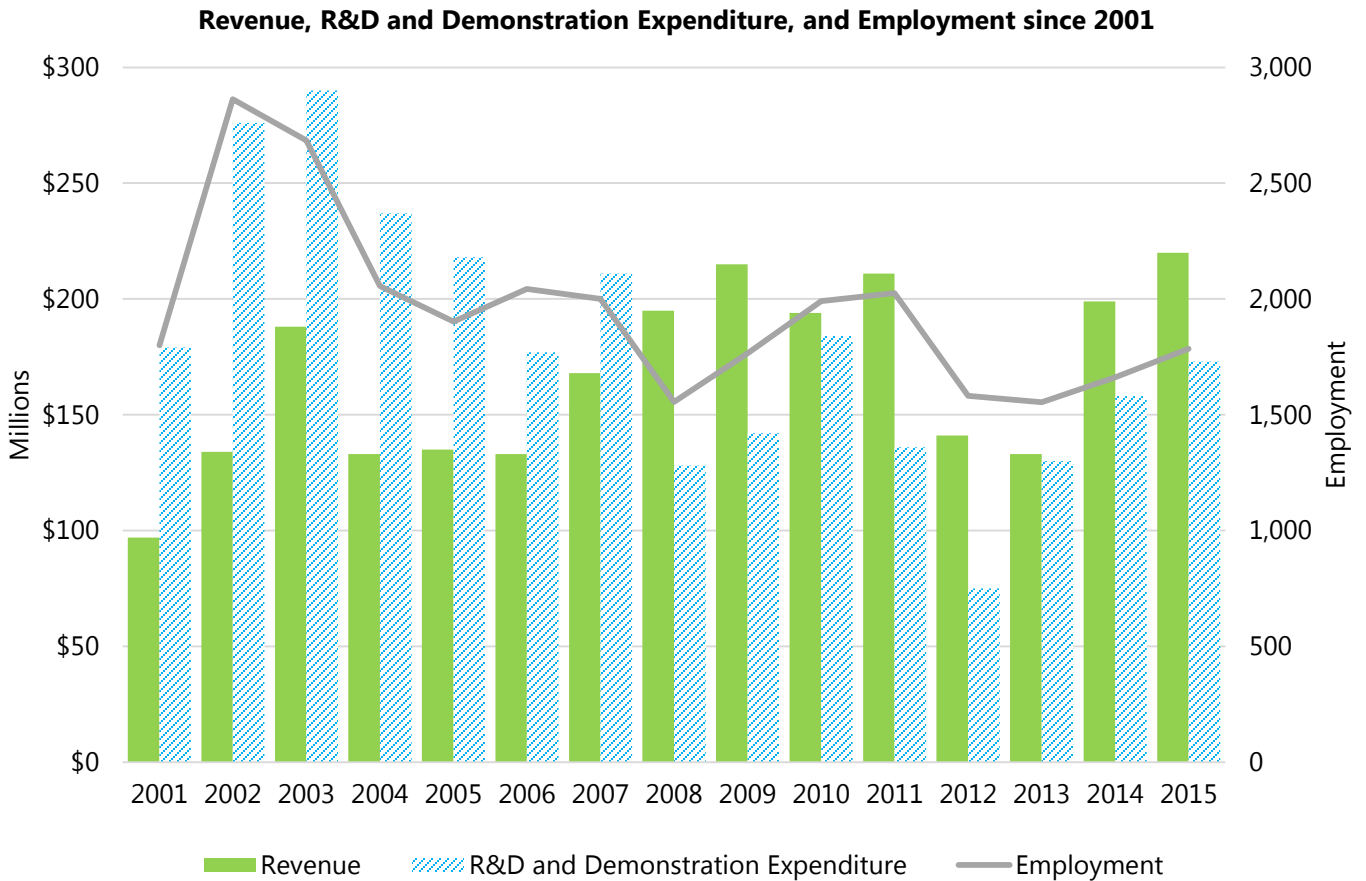
Biogas, which stems from the anaerobic decomposition of organic matter, such as sewage, manure, or green waste, is a renewable fuel produced by water treatment plants, landfills and agricultural digesters. **Quadrogen Power Systems, Inc.**, headquartered in British Columbia, has developed a technology that can remove contaminants from biogas and enable it to be used as fuel for reciprocating engines, gas turbines, fuel cells, and process reformers. Quadrogen's **C³P Process** enables the co-production of six main products: electricity, heat, hydrogen, biomethane, biodiesel, and carbon dioxide. These products can be used on site by the consumer as renewable heat and power sources or can be sold as green products to third parties. (<http://www.quadrogen.com/>)

CONCLUSION

The Canadian hydrogen and fuel cell sector is recognized for its role in the development of clean technology applications. In 2015, approximately 60% of survey respondents reported involvement in hydrogen and fuel cells activities for more than 10 years, which suggests a sector with a stable base of organisations. Research was the largest area of focus and expertise for most survey participants, with their top priorities for 2016 being technology development, collaboration, and strategic alliances.

In 2015 survey respondents from the Canadian hydrogen and fuel cell sector reported:

- Revenue of \$220 million.
- \$125 million of revenue from product sales.
- \$84 million of revenue from the provision of services.
- Research, development and demonstration expenditures of \$173 million.
- Employment of 1,785 jobs.
- Over 18 demonstration projects.
- 98 strategic alliances.
- 222 research partnerships.



Canadian Hydrogen and Fuel Cell Association (CHFCA)

The Canadian Hydrogen and Fuel Cell Association (CHFCA) is the national association accelerating Canada's world recognized hydrogen and fuel cell sector. As the sector's collective voice, the CHFCA works to raise awareness of the economic, environmental, and social benefits of hydrogen and fuel cells. It is a national, non-profit association providing services and support to Canadian corporations, governments, and educational institutions promoting development, demonstrating and deploying hydrogen and fuel cell products and services in Canada. Its members cover most types of hydrogen and fuel cell technologies, components, systems supply and integration, fuelling systems, fuel storage, and engineering and financial services.

The CHFCA was formed in January 2009 as a result of a merger between the Canadian Hydrogen Association (CHA) and Hydrogen & Fuels Cells Canada (H2FCC). The merger unites the members of the former associations to create a vibrant, influential association that represents the majority of the stakeholders in Canada's hydrogen and fuel cell sector.

Innovation, Science and Economic Development Canada (ISED)

Innovation, Science and Economic Development Canada's goal is to enhance the competitiveness of Canadian industry. This federal government department is responsible for maintaining channels of communication with key sectors to facilitate informed advocacy of industry interests in government decision-making, and to convey the government perspective back to industry; analyzing the challenges and opportunities that face key sectors in the economy; developing policy options for possible government response to extraordinary challenges and opportunities; and delivering the subsequent programs and services.

MNP LLP

MNP is the fastest growing major accountancy and business consulting firm in Canada, with more than 70 locations and 3,000 team members across the country. Economic and industry studies are carried out by MNP's Economics and Research practice. Based in Vancouver, the Economics and Research practice consists of a team of dedicated professionals that have a successful track record of assisting clients with a wide variety of financial and economic studies. Its work has encompassed a wide range of programs, industries, company operations and policy initiatives, and has helped clients with decision-making, communication of economic and financial contributions, documentation of the value of initiatives and activities, and development of public policy.



www.chfca.ca



www.ic.gc.ca



www.mnp.ca

METHODOLOGY

The 2016 Sector Profile is the thirteenth annual publication of information on the Canadian hydrogen and fuel cell industry. As in previous years, existing and potential members of the Canadian Hydrogen and Fuel Cell Association, educational institutes, government stakeholders, and partners in current hydrogen and fuel cell demonstration activities were asked to voluntarily complete a survey questionnaire.

While the survey questionnaire has remained substantially consistent from the survey's inception, organizers have refined the questions to gather more detailed information to better reflect the sector and its trends. Since the 2004 survey, specific questions have been asked from three types of stakeholders:

- Corporate (public and private organisations).
- Government (government and government agencies).
- Educational institutes and non-profit organisation (educational, non-profit, and non-governmental organisations (NGOs)).

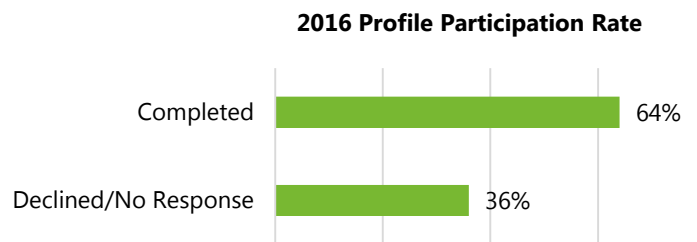
All monetary results are presented in Canadian dollars.

A total of 102 organisations associated with hydrogen and fuel cells in Canada were invited to participate in the development of this Sector Profile.

In total, 65 completed responses were received, representing an overall response rate of 64%. Not all respondents provided information for every category requested. Some investigation was conducted regarding the completeness of the data provided by respondents, or reasons for non-provision, but in some cases clarification was not received.

R&D expenditures provided by respondents were supplemented with awards for hydrogen and fuel-cell related R&D projects by Natural Sciences and Engineering Research Council of Canada (NSERC).

Note that industrial hydrogen production represents a large segment of the sector, but participation in the survey is likely low due to concerns about inferring financial information from survey data.



A list of survey respondents is included at the end of the report. Note that some respondents did not consent to having their organisation's name published in the sector profile.

Figures presented for 2015 were collected by an online questionnaire in early 2016. Figures presented for 2014 are as reported in the 2015 Sector Profile and, therefore, may not be fully comparable due to differing respondents and/or participation rate.

Please note that this report presents only direct impacts of the industry. Indirect and induced impacts (or multiplier impacts) associated with the industry were not part of the study.

Industry highlights throughout the report were prepared based on publicly available information and information provided directly by participating organisations.

2016 PARTICIPANTS

A.V.Tchouvelev & Associates Inc.	Institute for Sustainable Energy, University of Toronto
Associated Plastics & Supply Corp	IRDI System
AFCC (Automotive Fuel Cell Cooperation)	ITM-Power Plc
Ballard Power Systems Inc.	Lambton College
BioGenerator Energy Solutions Inc.	Linde LLC
British Columbia Ministry of Energy and Mines	Loop Energy Inc.
Canadian Hydrogen and Fuel Cell Association (CHFCA)	Mercedes-Benz Canada, Fuel Cell Division (MBFC)
Canadian Nuclear Laboratories (CNL)	National Research Council Canada
Carleton University (Department of Mechanical and Aerospace Engineering)	Natural Resources Canada
Catalysis Research for Polymer Electrolyte Fuel Cells	New Flyer Industries Inc.
Change Energy Services Inc.	Palcan Energy Corporation
CSA Group	Pathway Industries Inc.
Dana Canada Corporation	Polytechnique Montreal-Laboratory of New Materials for Electrochemistry and Energy
dPoint Technologies Inc.	Powertech Labs
Energy Systems Design Laboratory, University of Alberta	Quadrogen Power Systems, Inc.
Global Affairs Canada	Sacré-Davey Engineering Inc.
Greenlight Innovation Corp.	Simulent Inc.
Groupe de recherche sur les technologies et procédés chimiques et pharmaceutiques, Université de Sherbrooke	Sustainable Development Technology Canada
HTEC Hydrogen Technology & Energy Corporation	Terrella Energy Systems
Hydra-Energy Corporation	The CCS Global Group
Hydrogen In Motion Inc. (H2M)	Transport Canada
Hydrogen Research Institute, Université du Québec à Trois-Rivières	Truckenbrodt Clean Energy Consulting Inc.
Hydrogenics Corporation	TUGLIQ Energy Co.
Hyteon Inc.	University of British Columbia (UBC)
Hyundai Auto Canada Corp.	UOIT University of Ontario Institute of Technology
Innovation, Science & Economic Development Canada (ISED)	University of Ottawa
Institut National de la Recherche Scientifique (INRS)	Wazuku Advisory Group
	Whitefox Technologies Canada Ltd
	Xebec Adsorption Inc.
	XRG Energytech Solutions Inc.
	Zolair Energy Ltd

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